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IGR TRANSLITERATION OF RUSSIAN

The AGI Translation Office has adopted the essential features of Cyrillic transliteration recommended by the U. S Department of the Interior, Board on Geographic Names, Washington D. C.

Alphabet		transliteration
А	а	a
Б	б	b
В	в	v
Г	г	g
Д	д	d
Е	е	e, ye (1)
Ё	ё	ë, yë
Ж	ж	zh
З	з	z
И	и	i (2)
Й	й	y
К	к	k
Л	л	l
М	м	m
Н	н	n
О	о	o
П	п	p
Р	р	r
С	с	s
Т	т	t
У	у	u
Ф	ф	f
Х	х	kh
Ц	ц	ts
Ч	ч	ch
Ш	ш	sh
Щ	щ	shch
Ъ	ъ	" (3)
Ы	ы	y
Ь	ь	' (3)
Э	э	e
Ю	ю	yu
Я	я	ya

However, the AGI Translation Office recommends the following modifications:

1. Ye initially, after vowels, and after ъ, ь. Customary usage calls for "ie" in many names, e.g., SOVIET KIEV, DNIEPER, etc.; or "ye", e.g., BYELORUSSIA, where "e" follows consonants. "e" with dieresis in Russian should be given as "yo".
2. Omitted if preceding a "y", for example, Arkhangelsky (not "iy"; not "ii").
3. Generally omitted.

NOTE: Well-known place and personal names that have wide acceptance will be used. Some translations may include elements of previous German transliteration from the Russian; this occurs in IGR most commonly in maps and lists of references. The reader's attention is called to the following variations between German and English systems which may cause confusion when trying to check back to original Russian sources.

German	English
w	v
s	z
ch	kh
tz	ts
tsch	ch
sch	sh
schtsch	shch
ja	ya
ju	yu

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THE SPILITE-KERATOPHYRE FORMATION IN THE REGION OF THE BLYAVA DEPOSIT IN THE URAL MOUNTAINS (PART 2 OF 2)[1]

by

V.A. Zavaritsky

- translated by Grahame Spragg[2] -

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[1] Translated from Spilito-keratofirovaya formatsiya okrestnostey mestorozhdeniya blyavy na urale: Trudy Instituta Geologicheskikh Nauk, Issue 71, Petrograficheskaya Seriya, no. 24, 1946, p. 1-83. Edited by G.C. Amstutz, University of Missouri. Part 1 of this work was published in IGR, v. 2, no. 7, p. 551-576.

[2] University of Missouri, School of Mines and Metallurgy, Rolla, Missouri.

SECTION II. THE MOUNTAINOUS BELT WITH THE SPILITE-KERATOPHYRE FORMATION ON THE WESTERN SLOPE OF THE SOUTH URAL MOUNTAINS (CONCLUDED)

Chapter 4. Spilitic porphyrites and other rocks of intermediate composition

In this chapter are considered rocks, which in composition and petrographic features take up an intermediate position between spilites and keratophyres. Of the extrusive rocks of the normal earth-alkaline series porphyrites are similar to them, i. e. paleotypal rocks of an andesitic and dacitic composition.

In exactly the same way that the spilites described above change into diabases, the rocks here described change into ordinary porphyrites characterized by the presence of phenocrysts of zoned basic plagioclase. This transition into porphyrites, and also the similarity to them with regard to texture and general appearance becomes more evident under a microscope and by using the name "spilitic porphyrites", proposed by Zavaritsky, for the rocks being described, i. e. porphyrites, pertaining to a spilitic-keratophyric formation.

For analogous rocks from Karadag Levinson-Lessing proposed the name "keratopspilite". It expresses better the intermediate character of the rocks, but does not indicate their connections with porphyrites, and is therefore less suitable.

A comparison of the data of the petrography of the spilitic porphyrites of the Blyavinsky region with data about their geology enabled us to pick out several types, each of which will be examined separately.

Spilitic porphyrites from the neighborhood of Rakityanka settlement

These rocks are not very widespread and are encountered chiefly to the northwest of the Rakityanka settlement in the form of separate beds with a thickness of 2 to 3 m in a layer of keratophyric agglomerates.

Macroscopically they are porphyritic rocks with a light greenish or yellowish-grey coloring and phenocrysts of altered plagioclase.

Some darker varieties resemble in their outward appearance the common plagioclase porphyrites which are very widespread among the green rocks of the Ural mountains.

Phenocrysts: Nearly a third of the whole mass of the rock consist of phenocrysts of albitized plagioclase and occasional phenocrysts of monoclinic pyroxene.

The plagioclase has the appearance of tablet-shaped crystals of 1.0 to 1.5 mm. Usually they form aggregates, on account of which the texture of the rock is glomeroporphyritic. The crystals in the aggregates are often grown into each other. In the majority of cases the plagioclase appears like albite or albite-oligoclase, with an index of refraction less than that of Canada balsam. The data of the measurements of the twins show that it contains from 5 to 18 percent An. In albitic twins with coinciding X and X' angles $Z \wedge Z' = 8$ to 30°. Maximum extinction in the zone $\perp$ (010) is from -10° to 0°. Secondary albite is always greatly argillized and speckled with very small scales of sericite (?).

Partially albitized basic plagioclase was observed in a few thin sections. The replacement by albite sets in from the periphery of the phenocrysts, from the cracks of the cleavage, from the twin plane and so on. The albite, penetrating into the plagioclase, forms a dense net of very fine intersecting veinlets. In the most albitized crystals plagioclase was preserved only in the form of separated, not very large, and quite numerous particles which stand out amidst the dimmed albite by its own freshness and its high index of refraction. Such plagioclase greatly resembles those spotted feldspars which are described by Levinson-Lessing in analogous rocks from Karadag.

The basic plagioclase in the porphyrites here described appears to be labradorite. In a single phenocryst, with the albite twinning law, $B \wedge Z = 32^\circ$, $B \wedge Y = 59^\circ$, $B \wedge X = 75^\circ$, which corresponds to 59 percent An. The extinction in a section $\perp 100 = 31^\circ$. In another [phenocryst], now with Carlsbad twinning, $B \wedge Z = 70^\circ$, $B \wedge Y = 31^\circ$, $B \wedge X = 47^\circ$, i. e. 48 percent An.

Monoclinic pyroxene is not always encountered. Its phenocrysts have a short-prismatic or isometric shape and the size varies from 0.3 to 2 mm. The pyroxene is perfectly colorless, $\beta = 1.69\pm$, $\gamma - \alpha$ is about 0.030, $2V = +56^\circ$ and $C \wedge Z$ - about 40°. It is probably nearer to diopside in composition than the pyroxene of spilites.

Matrix: Spilitic porphyrites of this type have a fully-crystalline, though also very small grained matrix. It is formed from microlites of argillized albite (0. 05 to 0. 1 mm) and small needles of uralitic hornblende (up to 0. 03 mm) found between them. Between the microlites there are sometimes found small grains of pyroxene (0. 01 to 0. 02 mm), only partially converted into amphibole.

The texture of the matrix is pilotaxitic, since their microlites are arranged subparallel. This texture is preserved even in those occasional cases where there are more small needles of uralite than microlites of albite.

Secondary quartz, chalcedony, calcite and many other minerals that are not always determinable are discovered in the matrix in the form of fibers and spots, or occasional amygdules are filled out. In one thin section several amygdules are filled by albite, in another a deep emerald-green mineral similar to chlorite is present. It forms very fine scaly aggregates.

On the whole the matrix of the rocks being described looks very altered.

Spilitic porphyrites from the neighborhood of the village of Herzonka

More to the north and west of the village of Herzonka these rocks compose a whole layer between spilites and keratophyres. The thickness of this layer reaches some tens of meters, but it is composed of many beds, the thickness of which in those places that lend themselves to measurement, does not exceed 2 to 3 m.

Macroscopically spilitic porphyrites of this type have the appearance of dark aphanitic rocks of a yellow-grey color with a red-brown tint. Porphyritic phenocrysts are not seen. Sometimes rounded amygdules filled by calcite are seen.

Phenocrysts: Porphyritic phenocrysts are rarely encountered in the rocks here described. They are not very large tablets of plagioclase (0. 5 mm).

Plagioclase in phenocrysts appears like albite, usually not argillized. Twins, particularly polysynthetic twins, are rare. In one Carlsbad twin $B \wedge Z = 80^o$, $B \wedge Y = 19^o$, $B \wedge X = 74^o$, which corresponds to 10 percent An. In another, formed by the law Ala - A, $B \wedge Z = 84^o$, $B \wedge Y = 73^o$, $B \wedge X = 20^o$, which results in 7 percent An. The position normal to the plane of intergrowth in this same twin [$\perp$ (100)] is determined by the coordinate values: $B \wedge Z = 75^o$, $B \wedge Y = 28^o$, $B \wedge X = 66^o$, which results in 5 percent An. In the center of some phenocrysts there were preserved small portions of basic plagioclase, differing from albite by a higher index of refraction and by the character of the extinction (to the other side). Judging from the angle of extinction the plagioclase contains not less than 40 percent An.

The monoclinic pyroxene is in great part colorless, but sometimes it has a hardly noticeable brownish coloring. $\beta = 1.68 \pm$, $\gamma - \alpha = 0.028$ to 0.030; $C \wedge Z = 40$ to 41^o; $2V = +55^o$.

Matrix: The composition and texture of the matrix of the rocks being described depends on the degree of their crystallinity. In the least crystalline varieties the matrix is formed by: 1) a semi-transparent aggregate, apparently consisting of albite found in it in a comparatively small quantity (30 to 40 percent). Here the texture of the matrix is hyalopilitic, but the microlites are arranged subparallel (fig. 18b), which brings the texture nearer to a pilotaxitic one. The microlites do not exceed 0. 05 mm in length. Small fine grains of magnetite are evenly dispersed throughout the rock.

In the varieties which are a little more crystalline and which predominate among spilitic porphyrites of this type, the microlites of albite now compose more than 60 to 70 percent of the matrix. Between the microlites, that are here up to 0. 1 to 0. 2 mm in length, small lumps of chlorite are found which have been formed in place of small grains of pyroxene. The latter were still preserved here and there. Magnetite is encountered in occasional, larger grains (0. 05 mm).

The texture of the matrix here is pilotaxitic (fig. 18a). It is particularly well marked in the most crystalline rock type from the neighborhood of the Nikitino settlement (fig. 18c). This rock in contrast to typical spilitic porphyrites possesses no pyroxene, either in the matrix or in the form of phenocrysts. Here there is a little more secondary quartz.

Chemical composition: The chemical composition of the most widespread variety of the rocks being described is given in Table 4.

From these data it can be seen that with regard to chemical composition a spilitic porpyhrite represents a special species of rock. It differs from andesite, which is nearest to it, in a higher ratio of alkalis to feldspathic lime, and in the absence of lime in the composition of dark colored components.

So, spilitic porphyrite is related to andesites in the same way that spilites are related to basalts.

Hornblende porphyrites and rocks connected with them

The spilitic porphyrites described above are

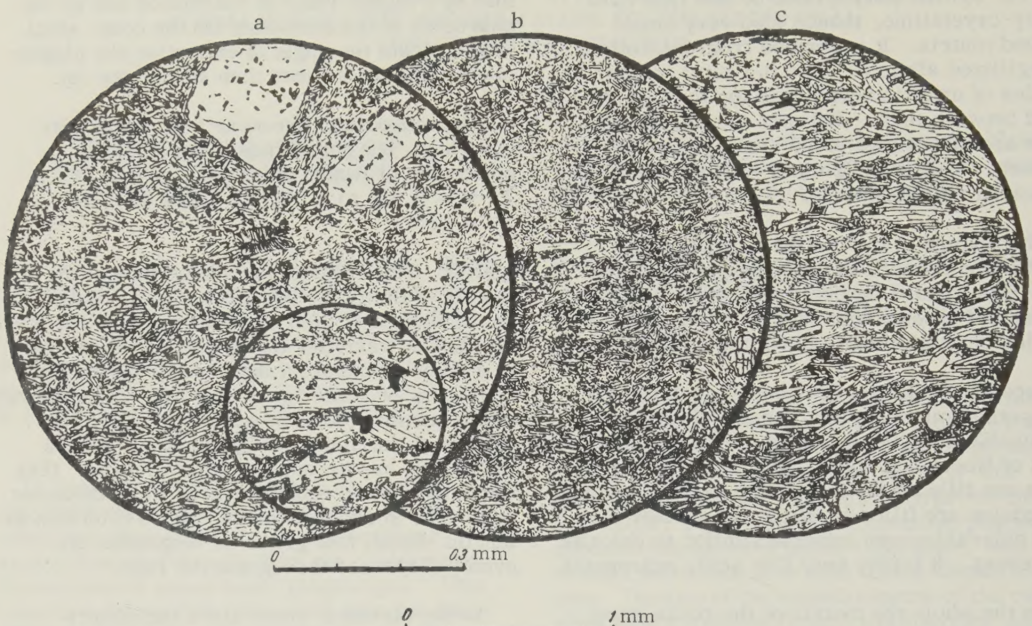

FIGURE 18. a) A spilitic porphyrite from the neighborhood of the village Herzonka. Rare phenocrysts of albite and pyroxene. A pilotaxitic matrix. In the small circle the matrix is very greatly magnified. b) The least crystalline variety of the same rock. c) The most crystalline variety from the neighborhood of Nikitino settlement. A typical pilotaxitic texture. Fine round amygdules, filled by quartz.

TABLE 4. Chemical composition of a spilitic porphyrite from the neighborhood of the village of Herzonka.

Components	Sample no. (see note)	
	7	
	weight percent	mol. no.
SiO_2	55.44	923
TiO	0.95	011
Al_2O_3	18.21	178
Fe_2O_3	9.45	059
FeO	1.44	020
MnO	0.16	003
MgO	1.67	041
CaO	3.60	064
Na_2O	6.62	106
K_2O	0.25	003
H_2O+110°	2.04	
H_2O- 110°	0.49	
CO_2	0.30	
Total	100.62	

Numerical characteristics according to A.N. Zavaritsky.

Sample no. (see note)
7
a = 15.5
c = 4.6
b = 13.6
s = 66.3
n = 97
f' = 74
m' = 21
c' = 5

Sample no. 7. A spilitic porphyrite from the region of the village of Herzonka, specimen 19 [9] 1934. The analysis was carried out in the laboratory of Ts. N. I. G. R. I. (Control Scientific Research Institute of Geological Survey, Ed.).

analogous to the rocks of an andesitic composition. Hornblende porphyrites are a group of more silicic rocks possessing the composition of dacite. In this respect they are nearer to keratophyres than to spilites. Geologically, they are also associated more with keratophyres than with spilites. Probably, many keratophyres represent a product of automatomorphism of these very rocks.

The [main] features of hornblende porphyrites appear to be: 1) the absence or faint appearance of albitization of zoned plagioclase in the phenocrysts, 2) the presence of primary hornblende and 3) the presence of quartz in the matrix.

The spread of these rocks is apparently considerable. They are encountered especially

often in agglomerates in pieces from 3 cm to 1 to 15 m, together with fragments of keratophyres. Besides that, separate flows of these rocks are encountered, sometimes of considerable thickness (up to 5 to 7 m). Stratigraphically these rocks are related in time to the layer of clastic volcanic rocks.

In outward appearance hornblende porphyrites greatly differ from spilites and spilitic porphyrites, and differ slightly from keratophyres. They are very hard, dense rocks with an even conchoidal fracture, a light-grey or a yellowish-grey coloring, and occasional fine (up to 2 mm), porphyritic phenocrysts of a white feldspar and black hornblende. The latter seems to be the only feature that makes these rocks different from keratophyres.

Phenocrysts: Under the microscope these rocks always possess a porphyritic texture, but the relative quantity of phenocrysts in them varies greatly. There are encountered in the form of phenocrysts: 1) a zoned and sometimes albitized plagioclase, 2) a brown hornblende and 3) monoclinic pyroxene. Occasional, comparatively large grains of magnetite also have the appearance of phenocrysts. Fine, small prisms of apatite are found together with it. On two occasions there were observed strongly melted [corroded, embayed] phenocrysts of quartz about 0.1 mm in size.

The plagioclase in great part appears to be zoned basic andesine. The zoning is usually very well displayed. In the center of the larger phenocrysts there is up to 50 percent An. In Carlsbad twinning $B \wedge Z = 67^o$, $B \wedge Y = 53^o$, $B \wedge X = 45^o$. In albite twinning $B \wedge Z$ = 27 to 23°, $B \wedge Y$ = 66 to 68°, $B \wedge X$ = 80 to 85°. The extinction in sections $\perp$ [100] = (+) 25 to 27°. In the periphery the composition of the plagioclase reaches the composition of oligoclase with 23 to 27 percent An (the extinction in the section $\perp$ [100] is not more than + 7 to 8°). The transition from acidic plagioclase to more basic plagioclase is usually gradual, but sometimes the zones are sharply separated from one another. An interchange of zones was observed in some phenocrysts. A partial albitization of plagioclase was observed in almost every thin section. The more basic plagioclase is in the main replaced, i.e. the centre of the phenocrysts (fig. 19). Secondary albite is always strongly argillized and speckled with small tablets of prehnite. Fully albitized plagioclase was observed comparatively rarely. However, in some rocks only albite together with phenocrysts of hornblende are found. In phenocrysts of the albite concentrated zones of inclusions of secondary minerals are observed, showing that the primary plagioclase was zoned.

Secondary albite contains not less than 10 to 12 percent An. In Carlsbad twinning $B \wedge Z = 78^o$, $B \wedge Y = 20^o$, $B \wedge X = 73^o$. Maximum extinction in a zone $\perp$ (010) = 8 to 12°. The phenocrysts of plagioclase are equant, but each of them represents twinning of two small tablets. Sections $\perp$ [100] possess square outlines, and sections of (010) are rectangular. The majority of phenocrysts have a size of several tenths of a millimeter, but some of them reach 1.5 to 2 mm. Fine phenocrysts represent somewhat corroded fragments of larger crystals. The hornblende in these rocks attract attention no less than [the?] zoned plagioclase. A slightly unusual coloring is characteristic for it, which in the direction of Z is brown with a greenish tint, in the direction of Y is greenish brown with a faint, but sometimes quite clear, violet tint, and in the direction of X is a light greenish yellow. The other optical properties are: $\gamma = 1.689$, $\beta = 1.676$, $\alpha = 1.660$; $\gamma - \alpha = 0.028$ to 0.030; 2V = 72 to 76°, but sometimes it diminishes to -65°; $c \wedge g$ = 15 to 17°; dispersion $\rho < \upsilon$; absorption Z>Y>X. Simple twins are very widespread with B = $\perp$ [100]. The phenocrysts have more or less rounded outlines, since they are always corroded [embayed] (fig. 19). Sometimes on account of this, characteristic "inlets" show up in them. In many phenocrysts there is observed a very narrow opacitic border, almost unnoticeable when not greatly magnified, and only shading the outlines of the phenocrysts. In separate cases the width of the opacitic border reaches 0.02 to 0.4 mm. Phenocrysts of 0.5 mm prevail over others, but many reach 2 to 3 mm. Small phenocrysts appear to be the remains of larger phenocrysts, the cleavage preserved. It is difficult to form a judgment about the composition of the hornblende here described. Its optical properties differ from the properties of basaltic hornblende, common in intermediate extrusive rocks. The faint violet tint possibly indicates a content of Na_2O in the composition of this mineral.

Monoclinic pyroxene is usually present in smaller quantity than hornblende. The dimensions of the phenocrysts of the pyroxene do not exceed 0.2 to 0.3 mm. The optical properties of the pyroxene are: $\gamma = 1.712$, $\beta = 1.687$, $\alpha = 1.680$; $\gamma - \alpha$ = 0.030 to 0.035; 2V = (+) 56; $c \wedge Z$ = 40 to 42°. The pyroxene is perfectly colorless. Twins are often encountered with B = $\perp$ (100).

Matrix: Hornblende porphyrites usually have a felsitic or coarse felsitic matrix, consisting of feldspar and quartz. The feldspar is always more or less argillized. Apparently it is albite, since the index of refraction of it is only slightly less than that of Canada balsam. Separate microlites of albite, 0.02 to 0.03 mm in length, sometimes stand out in the felsitic matrix. In slightly albitized rocks it is the microlites of andesine that stand out noticeably on account of their high index of refraction. Small grains of primary quartz are not easily distinguished in the matrix, but apparently,

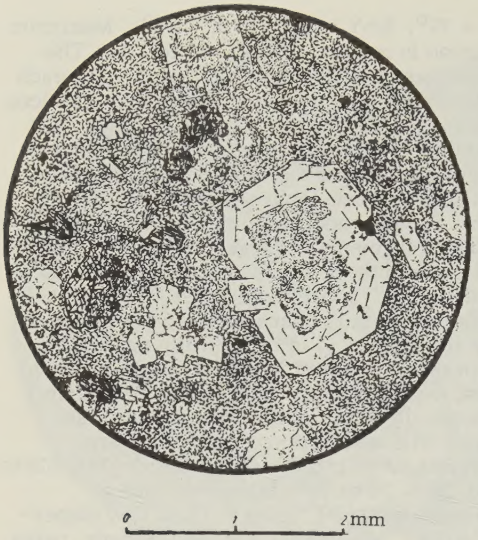

FIGURE 19. Hornblende porphyrite from the neighborhood of the village of Rakityanka. A large phenocryst of zoned andesine, replaced in the center by albite. In the upper part is fully albitized plagioclase. A corroded phenocryst of brown hornblende. A felsitic matrix.

there are not fewer of them than in other dacitic rocks. Magnetite is found in small grains, less than 0.01 mm in size, and are distributed quite evenly.

Secondary or hydrothermal [deuteric] minerals are represented by: green chlorite, calcite, chalcedony, quartz, and albite. They replace phenocrysts of plagioclase (calcite, chlorite), fill out in large quantities elongated amygdales of an irregular shape (chalcedony, quartz, calcite) form veinlets, cutting the whole rock, and more rarely develop in the matrix replacing it. Hydrothermal [deuteric] albite is encountered together with quartz in an amygdale.

There are many small prisms of apatite in accumulations of chlorite. The same small prisms also form inclusions in large grains of magnetite. Generally there is more apatite in these rocks than is usual.

Besides the felsitic matrix, micropoikilitic and felsitopilitic textures were observed in hornblende porphyrites. Micropoikilitic textures in these rocks are characterized by the small dimensions of the oikocrysts (0.05 to 0.08 mm). Microlites found in them do not exceed 0.01 mm. Sometimes oikocrysts consist of albite.

These can be called felsitopilitic textures, in which microlites of albite predominate over the micro-felsitic mass containing them. Textures of this kind together with hydrothermal ones can be attributed to andesitic textures.

Chemical composition: A specimen of hornblende of a porphyrite with slightly albitized plagioclase was analysed. The results of the analysis are given in Table 5.

From these data it can be seen that in chemical composition hornblende porphyrite is closer to silicic rocks than to intermediate ones. The number of colored components (b) are fewer in it than in dacite. Of the intermediate types alkalic granite according to Daly is nearest to it, differing only by a different ratio of $Na_2O : K_2O$ (n) and by the absence of lime in the colored components.

Chapter 5. Keratophyres

In the majority of cases keratophyres appear to be silicic rocks of the formation being examined, and they can be compared to rhyolites or quartz-porphyrites of a normal calc-alkalic series. The main feature that makes them differ from quartz-porphyrites appears to be that the feldspar consists exclusively of albite. This has already been noticed by geologists of the Urals, among whom the rocks became known as albitophyres.

Phenocrysts of quartz, generally characteristic for silicic extrusive rocks, are absent in many keratophyres, although this alone still does not point to the fact that these keratophyres have a more basic composition. Quartz is usually found in a matrix of keratophyres, so that the keratophyres appear as crypto-quartz- or quartz-bearing rocks. Varieties without quartz also exist, but it is impossible to single them out into a separate group, since under a microscope quartz is also not always distinguishable in quartz-bearing rocks. It is impossible to divide keratophyres also in respect to gross chemical composition, firstly, because of the lack of analyses, and secondly because of secondary changes.

At the base of the classification of these rocks there ought to be put the microtexture of the matrix, which best conveys the primary composition of the lavas that have flowed out. On this basis three main types can be singled out among the keratophyres of the formation being examined: 1) keratophyres with microlitic textures of the matrix, 2) keratophyres with a felsitic or spherulitic matrix, and 3) quartz keratophyres with phenocrysts of quartz and a spherulitic or felsitic matrix.

Microlitic textures, as is known, are not characteristic for acidic extrusive rocks, and so keratophyres with a pilotaxitic or hyalopilitic (or rather felsitopilitic) matrix in the majority of cases can be considered as a product of the autometamorphism of intermediate lavas, despite the fact that their com-

TABLE 5. Chemical composition of hornblende of a porphyrite

Components	Sample no. (see note) 8 weight percent	mol. no.
SiO_2	69.08	1.150
TiO_2	0.40	005
Al_2O_3	14.55	143
Fe_2O_3	1.12	007
FeO	2.27	032
MnO	0.08	001
MgO	0.75	018
CaO	3.16	056
BaO	0.06	-
Na_2O	5.00	081
K_2O	1.96	020
H_2O+110°	1.10	
H_2O-110°	0.20	
P_2O_5	0.31	
S	0.05	
Total	100.08	

Numerical characteristics according to A. N. Zavaritsky.

Sample no. (see note) 8
a = 13.7
c = 2.8
b = 5.3
s = 78.2
n = 80
f' = 59
m' = 23
c' = 18

Sample no. 8. Hornblende porphyrite with zoned plagioclase from the neighborhood of Rakityanka salt, specimen 94/1939. The analysis was carried out in the laboratory of the An SSSR (Academy of Sciences of the U. S. S. R.).

position is often identical to the composition of keratophyres with a spherulitic texture. These keratophyres are analogous to those rocks from Karadag, which F. Y. Levinson-Lessing called keratophyrites.

Among keratophyres there were no rocks encountered, that, like diabases among the spilites, may have changed directly into them, and in such a way that they indicated the primary composition of the lavas that had flowed out. This makes their petrographic study difficult.

Keratophyres with a microlitic matrix

These rocks are often encountered, but almost always in the form of small separate flows in keratophyric agglomerates or in underlying beds of keratophyres. Some varieties form thin dikes (1 to 1.5 m) in siliceous schists.

Macroscopically these keratophyres differ little from others although in the majority of cases they have a darker, sometimes almost black coloring, on account of the concentration of the oxides of iron. Fine phenocrysts of albite (1 to 2 mm) are very rare or completely absent. Amygdules of a greatly elongated lenticular shape are encountered, filled by quartz or chalcedony.

Sometimes flow structure is observed, caused by interchange of thin (up to 1 mm), darker belts with concentrated oxides of iron, with lighter ones. Many of these rocks have a breccia-like structure. Sometimes they are true breccias of acute-angled fragments uniform in composition, but very diverse in size, closely adjoining one another, or cemented by calcite.

Phenocrysts: In thin sections phenocrysts in great part are either completely absent or are represented by several small tablets all of albite not more than 0.5 to 0.8 mm in length.

In the rocks, where there are more of these small tablets, they form glomeroporphyritic aggregates, in which are found 2 to 3 and sometimes more than ten of these small tablets.

The albite in the phenocrysts is comparatively little argillized. The inclusions of secondary calcitic minerals are absent in it. In the center of the larger tablets (1 to 1.5 mm) there may be found concentric zones of chlorite inclusions.

The content of anorthite molecule in the albite is not more than 10 percent. The maximum extinction in a zone $\perp$ (010) fluctuates from -10° to -15°. Polysynthetic albitic twins are comparatively rare. In more widespread simple Carlsbad twins $B \wedge Z$ = 75 to 80°, $B \wedge Y$ = 18 to 15°, $B \wedge X$ = 30 to 83°, which corresponds to 5 to 7 percent An. In a simple Manebach twin $B \wedge Z$ = 80°, $B \wedge Y$ = 25°, $B \wedge X$ = 66°, which corresponds to 5 percent An. The index of refraction (β) in two phenocrysts measures a little less than 1.530.

In keratophyres encountered among spilitic porphyrites near the village of Herzonka there were observed, besides small tablets of albite that were not numerous, random grains of monoclinic pyroxene, 2V = +55°, $c \wedge Z$ = 40°, about 0.2 mm in size. These rocks can be

considered as transitional between spilitic porphyrites and keratophyres, but in composition and texture of the matrix they are nearer to the latter.

Matrix: The varieties of the keratophyres here described are distinguished according to the texture and composition of their matrix.

The first variety has a typical pilotaxitic matrix formed almost entirely of very fine microlites of albite (0. 05 to 0. 1 mm) arranged subparallel. Between the microlites is found only a small quantity of chlorite, oxides of iron, and other products of decomposition. There are almost no small allotriomorphic grains of quartz and albite here.

The second and more widespread variety differs from the first in that between the same, or still finer, microlites there are in the matrix more almost submicroscopic grains of quartz, albite and other products of crystallization of the glassy mesostasis. Thus the texture of this variety is "felsitopilitic", analogous to a hyalopilitic texture of rocks of an andesitic composition. In the rock here described there are not so very many microlites of albite less than in the preceding rock, and they are not always arranged subparallel.

The microfelsitic mass of quartz and albite was subject in places to a re-crystallization. Therefore changes to micropoikilitic textures are often observed.

A micropoikilitic matrix is characteristic for the third variety of keratophyres being described. In it the same fine numerous microlites of albite arranged subparallel are found in the oikocrysts of quartz or albite, which have quite large dimensions (up to 1 mm) and odd, diffused outlines. It is possible to distinguish the albite in the oikocrysts from quartz, only after having determined its biaxial nature on a universal stage. Its presence in the rocks apparently indicates a re-crystallization or albitization during autometamorphic transformation.

Secondary or hydrothermal minerals in all three varieties are represented mainly by chalcedony and quartz, which fill out the amygdules elongated in the direction of the arrangement of the microlites, and form clusters in the matrix. From time to time there were observed veinlets of calcite and accumulations of chlorite.

Keratophyres with a felsitic and spherulitic matrix

These rocks are most widespread among keratophyres. They make up a large part of the mass of extruded keratophyres and many dikes in the spilites. Spherulitic varieties are encountered among them more often than felsitic ones, which are usually found in the form of small layers among clastic volcanic deposits.

Macroscopically the keratophyres of this type differ from the preceding ones by a lighter yellowish-grey or grey coloring. The keratophyres in natural outcrops have this yellowish-grey coloring. The keratophyres at a depth are light grey, as the specimens from a bore-hole show.

Felsitic varieties represent very dense aphanitic rocks with an even conchoidal fracture. Among the spherulitic varieties are also encountered those which seem to be fine-grained. Fine porphyritic facies are often encountered, but in great part the keratophyres are represented by aphanitic varieties.

Phenocrysts: Keratophyres with a spherulitic texture do not have many phenocrysts. Sometimes it is possible to encounter only a few small tablets of albite 0. 5 mm in length. The albite is a little argillized and contains almost no anorthite (5 to 8 percent). In keratophyres with a felsitic texture phenocrysts are more common. Sometimes there are many of them, and the rocks clearly have a glomeroporphyritic texture. Here too there is albite that has grown somewhat turbid (7 to 12 percent An.). However, in several thin sections there were observed phenocrysts of potash feldspar, which is replaced by albite only in the periphery. Sometimes the small albitized selvage is very narrow, and sometimes only the remains of primary feldspar are found in the albite. The dividing line between the albite and the potash feldspar is diffused or, on the contrary, sharp and wavy, as in the case of metasomatic replacements (fig. 20b).

The potash-feldspar is recognized by the absence of argillization, by a parallel extinction in the zone $\perp$ (010) and, mainly, by an index of refraction lower than that of albite. Sometimes this feldspar possesses a moire structure. Usually, there are many scales of chlorites and other foreign inclusions in it, which prevents us from determining its composition.

In one thin section of a keratophyre with a felsitic matrix oligoclase is found in the phenocrysts, which are also replaced by albite only in the periphery. The oligoclase is recognized by thin polysynthetic twins and by an almost parallel extinction [from 0 to $+5^{\circ}$] in a zone $\perp$ (010). Without an analyzer it is no different from albite, since it is also argillized and speckled with small scales of sericite. The albite in the small borders do not possess twins, and its extinction in a zone $\perp$ (010) reaches -15°. Besides phenocrysts of albite random phenocrysts of quartz were encountered in the keratophyres. Pseudomorphs of chlorite after the light minerals, in great part after pyroxene,

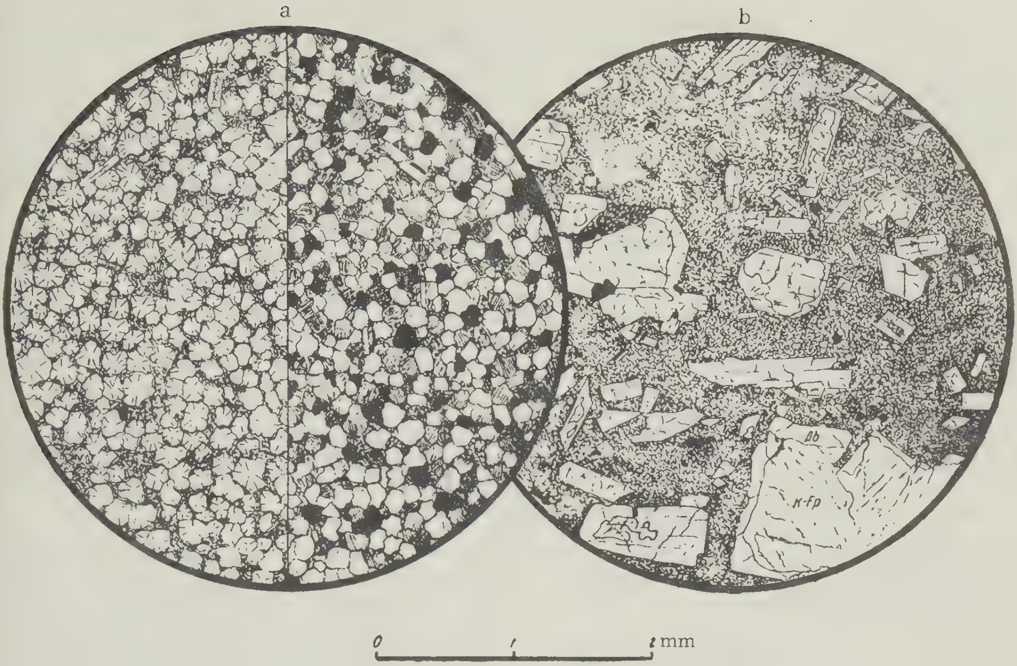

FIGURE 20. Keratophyre from the neighborhood of the Yaman-Gas deposit. a) "Metaspherulitic" texture of the keratophyres. (On the left) the spherulites can be seen without an analyzer. Under crossed nicols (on the right) each spherulite looks like single grain. b) Phenocrysts of potash feldspar (K-Fp) replaced by albite (Ab) along the periphery.

and sometimes also after hornblende, were observed in several felsitic varieties. Such keratophyres were formed probably as a result of autometamorphism of the hornblende porphyrites described above.

Matrix: The felsitic matrix is not worthy of special attention. It is usually coarse-felsitic with many small grains of quartz (0.01 to 0.03 mm). Sometimes on account of collective crystallization in the solid state the quartz grains reach 0.05 to 0.08 mm. The composition of the felsitic mass cannot always be determined under a microscope. The quantity of quartz here is rather substantial.

The matrix with a spherulitic texture was of two types: in some cases it consists wholly of spherulites, in others the latter are comparatively thinly distributed in a felsitic mass. The matrix of the first type is more abundant. It consists of perfectly round spherulites, 0.08 to 0.1 mm in diameter, adjoining each other. A little chlorite is found in the small spaces between the spherulites.

Spherulites have usually been subjected to collective crystallization. In the crossed nicols it can be seen that they are not radial-fibrous, but have taken on the appearance of large rounded grains with diffused outlines. Sometimes each spherulite breaks up into several irregular grains.

The radial arrangement of the very fine inclusions indicates that the round grains were once real spherulites. This can be distinctly seen without an analyzer (fig. 20a).

Thus the texture of these rocks no longer appears to be spherulitic. It is possible to call it metaspherulitic, although usually the prefix "meta" is used for the designation of a change under the influence of outside factors. Michel Levy called a similar texture globular (Structure globulaire), but this term does not express the connections with real spherulitic textures, and is therefore loose.

Analyses with a universal stage showed that rounded grains in a metaspherulitic matrix appear more often like grains of an uniaxial mineral, i.e. of quartz. However, there are also those which consist of albite.

Real spherulites with a radial-fibrous structure are chiefly found in textures of a secondary type, i.e. they are phenocrysts in a felsite matrix. Their sizes vary from 0.03 to 0.04 mm. Keratophyres, consisting wholly of real spherulites, are comparatively rare. Spherulites are formed from fibers with a negative elongation,

i.e. apparently only of albite. Albite has less of a tendency towards re-crystallization.

Rare fine microlites of albite in spherulitic keratophyres are either found between the spherulites together with chlorite, or form inclusions in the latter.

Quartz-keratophyres

Quartz-keratophyres are put into a separate group because they represent the most silicic rocks of the formation being considered. Besides that, it is easy to distinguish them from other keratophyres on account of the phenocrysts of dark glassy-limpid quartz.

Quartz-keratophyres compose either vertical and steeply dipping dikes, with a thickness from 1 or 2 to 30 or 40 m, or flows related to the uppermost layers of the series of extrusive rocks. Near the Blyavinsky deposit such flows are rare, but they are widespread near the Yaman-Gas deposit and in [the area of] the mouth of the Blyava, where they are interbedded with tuffs of the same composition.

In many places quartz-keratophyres change gradually into the keratophyres with a spherulitic matrix described above. In the latter there are sometimes observed sections with phenocrysts of quartz.

Phenocrysts: There are more phenocrysts in quartz-keratophyres than in the preceding rocks. The phenocrysts are mostly quartz. Here too there are not many phenocrysts of albite.

Phenocrysts of bipyramidal quartz, common for silicic extrusive rocks, are always more or less corroded and often have characteristic "inlets" and other shapes of corroded crystals. The dimensions of the quartz phenocrysts vary from 0.2 to 3 or 4 mm, but phenocrysts of 0.5 to 1.0 mm prevail. The small phenocrysts sometimes have well formed shapes and are slightly corroded and sometimes they appear like the remains of larger phenocrysts.

In rocks with a spherulitic matrix a small spherulitic border is always observed around the phenocrysts of quartz.

Phenocrysts of feldspar consist of tablets 0.3 to 0.7 mm in length. They usually form glomeroporphyritic aggregates and are not corroded. There is also no spherulitic border around them. The feldspar, somewhat argillized albite, is usually without polysynthetic twins. The index of refraction measured in two phenocrysts is $\beta = 1.536 \pm 0.002$. Maximum extinction in a zone $\perp (010) = 15$ to 20°.

In several phenocrysts the albite forms borders only when the central parts are formed out of a more argillized feldspar with an index of refraction lower than in albite. This is apparently potash feldspar which was also noted in the preceding rocks.

Sometimes glomeroporphyritic aggregates of phenocrysts of quartz and feldspar are observed. They grow through each other, as is often the case in micropegmatitic textures. In several thin sections separate phenocrysts of quartz are almost absent; instead, numerous, large (to 2 mm), rounded sections of micropegmatite are found surrounded with exactly the same selvage that was observed around separate phenocrysts of quartz (fig. 21c). This indicates that the formation of micropegmatite continued up to the crystallization of the matrix.

Besides the quartz and feldspar in the form of phenocrysts there are sometimes encountered small scales of biotite partially or fully altered to chlorite.

Matrix: In texture and composition of the matrix the quartz-keratophyres do not differ from the preceding rocks. The matrix is also either felsitic, changing into microallotriomorphogranular, or spherulitic and metaspherulitic. Just as in the preceding group, spherulitic textures are encountered considerably more often than felsitic ones. In several quartz-keratophyres the matrix was subject to a lesser degree to collective crystallization, and it is formed out of real spherulites with a radial-fibrous texture. Sometimes a border of albite or quartz with a simultaneous extinction is observed around the real spherulites. This is apparently the result of partial re-crystallization.

Little chlorite is found between the spherulites which are closely adjacent to each other (fig. 21a). There are almost no microlites of albite. In rocks in which spherulites are not widely distributed in the matrix (fig. 21b), the latter consists of small allotriomorphic grains of quartz and feldspar, small scales of chlorite, and a small number of microlites of albite.

The chemical composition of the keratophyres.

The analyses of Table 6 present the chemical composition of all the varieties of keratophyres.

The following conclusions can be drawn from an examination of these data:

1. The quartz-keratophyres (10, 13) are close in chemical composition to the average type of rhyolites according to Daly, but they differ from it, having a smaller content of feldspathic lime (c), a considerably greater ratio of $Na_2O : K_2O$ (n), and a little larger content of alumina in the composition of the femic components (a').

TABLE 6. The chemical composition of the keratophyres

Components	9		10		11		12		13	
	weight percent	mol. no.	weight percent	mol. no.	weight percent	mol. no.	weight percent	mol. no.	weight percent	mol. no.
SiO_2	68.94	1147	75.26	1253	76.45	1273	76.72	1277	77.20	1285
TiO_2	0.45	006	0.30	004	0.30	004	0.26	004	0.22	003
Al_2O_3	13.35	131	13.15	129	10.71	105	12.68	125	12.64	124
Fe_2O_3	3.17	020	1.69	011	2.34	014	1.25	008	1.92	012
FeO	1.73	024	0.86	012	1.45	020	0.43	006	0.28	004
MnO	0.06	001	0.07	001	0.06	001	0.02	-	-	-
MgO	1.47	036	0.53	013	1.18	030	0.49	012	0.04	001
CaO	1.11	020	0.50	009	0.42	007	0.32	005	0.12	002
Na_2O	5.64	091	6.18	100	5.24	084	6.58	106	5.81	0.94
K_2O	1.19	013	0.20	002	0.24	002	0.26	003	1.00	0.11
$H_2O+110°$	1.85	-	0.98		1.28	-	0.29		0.24	-
$H_2O-110°$	0.90	-	0.52		0.57	-	0.90		0.40	-
Total	99.86		100.24		100.24		100.20		99.87	

Numerical characteristics according to A. N. Zavaritsky

	9	10	11	12	13
a	13.8	13.3	11.0	14.0	13.6
c	1.3	0.6	0.4	0.3	0.1
b	7.4	4.3	5.8	3.2	3.0
s	77.5	81.8	81.8	82.5	83.3
n	87	98	98	97	90
f'	59	53	54	44	61
m'	33	20	33	24	2
c'	6	27	13	32	37

Sample no. 9. A keratophyre without phenocrysts of quartz with a micropoikilitic matrix, specimen 26. From an article by Zavaritsky [1]. Sample no. 10. Quartz-keratophyre with a spherulitic matrix, specimen 18. From an article by Zavaritsky [1]. Sample no. 11. A keratophyre without phenocrysts of quartz with a spherulitic matrix, specimen 19/15/1934. From the neighborhood of the village of Herzonka. The analysis was carried out in the laboratory Ts. N. I. G. R. I. (Control Scientific Research Institute of Geological Survey). Sample no. 12. A keratophyre without phenocrysts of quartz with a pilotaxitic matrix, specimen 37/15/1934. From the neigborhood of the village of Herzonka. Sample no. 13. A quartz-keratophyre with a felsitic matrix, specimen 16v. From an article by Zavaritsky [1].

2. The keratophyres without phenocrysts of quartz do not differ (12), or differ little (9, 11), from quartz-keratophyres. The higher content of femic components (b) and the lower content of alumina in the composition of the latter (a') permit us to compare some of them (9, 11) with dacites, from which they differ in the same way that quartz keratophyres differ from rhyolites.

3. The hornblende porphyrite described above is close to keratophyres in chemical composition, but differs from them significantly by its larger content of feldspathic lime (6) and the presence of lime in the composition of the femic components (c').

The hornblende porphyrite differs from the keratophyres in chemical composition in approximately the same way a diabase [1, p. 31] differs from a spilite [2]. This confirms the assumption that a part of the keratophyres was formed from hornblende porphyrites as a result of their autometamorphism (albitization).

Chapter 6. Clastic volcanic rocks

Clastic volcanic rocks of the formation being described are represented mainly by agglomerates or volcanic breccias. In the large explosion-fragments and bombs of these breccias there are found the rocks that have already been described. Here, therefore, we consider only the tuffaceous cement of these agglomerates together with less widespread fine clastic rocks.

Tuffs of hornblende porphyrites

Tuff material possessing the composition of the hornblende porphyrites described above forms cement in the majority of agglomerates, despite the fact that keratophyres are encoun-

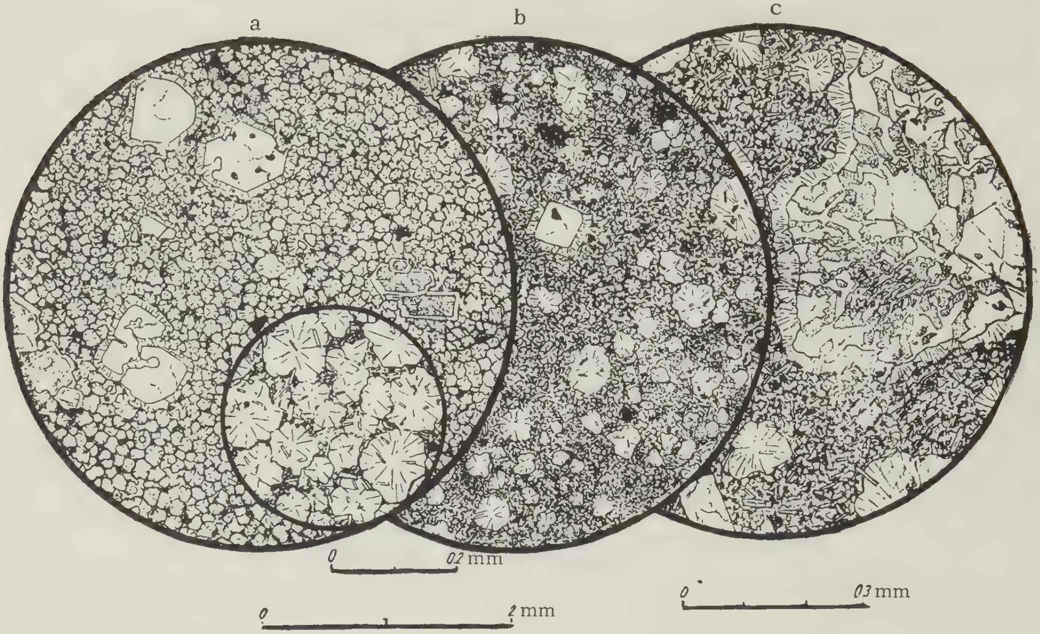

FIGURE 21. Quartz-keratophyres. a) the matrix is composed wholly of identical spherulites (in the small circle these spherulites are greatly magnified). Spherulitic borders are around the phenocrysts of quartz (the matrix consists of a felsitic aggregate and separate spherulites differing in size). b) A phenocryst of "micropegmatite" in the quartz-keratophyres from the neighborhood of the Yaman-Gas deposit. A spherulitic border is around these original formations.

tered more often in the large fragments. The number of these fragments sometimes diminishes, and the agglomerates change into uniform tuffs. In outcrops they are in great part greatly decomposed crumbly rocks with numerous veinlets of calcite and prehnite. In less altered dense tuffs a fragmentary texture is clearly visible; the separate fragments of the dark matrix and of the phenocrysts of white feldspar and black hornblende are different. Under a microscope it can be seen that these rocks in the majority of cases appear like lithoclastic tuffs, since they consist mainly of fragments of a matrix of porphyrites. The latter differs little in these fragments from a matrix of hornblende porphyrites of large explosion blocks or separate flows. It was apparently more glassy, judging from the fact that microlites of albite stand out more in it and traces of a perlitic structure are observed (fig. 22). It is now fully crystallized into a microfelsitic aggregate of feldspar, quartz, and a relatively large quantity of chlorite. There are often found in the fragments and matrix, phenocrysts of zoned basic, or partly albitized, plagioclase and phenocrysts of a brown hornblende and monoclinic pyroxene. Fragments of phenocrysts are rarely encountered. Grains of magnetite and numerous small prisms of apatite are found in fragments of the matrix.

The size of the fragments in the tuffs varies, but fragments of 1 to 2 mm prevail. The cement is ashlike with an argillaceous texture. There is less chlorite in it than in the fragments.

Tuffs of keratophyres

Among the tuffs of keratophyric composition there are distinguished: 1) Lithoclastic tuffs, consisting of fragments of a matrix of keratophyres with microlitic textures, 2) lithoclastic tuffs, consisting of fragments of a spherulitic and felsitic matrix of quartz-keratophyres, and 3) crystalline tuffs consisting of fragments of phenocrysts of quartz and feldspar.

Those consisting of fragments of keratophyres with microlitic textures differ from each other, as do also the lavas of the same type. In some, fragments of a micropoikilitic matrix prevail, in others there are more fragments with a pilotaxitic texture. Fragments of phenocrysts are rarely encountered. Small tablets of albite are sometimes found in fragments of the matrix. The presence in these tuffs of occasional fragments of phenocrysts of pyroxene and brown hornblende proved to be somewhat unexpected.

Lithoclastic tuffs of quartz-keratophyres are very widespread in some places. Primary fragmentary textures of these rocks often hardly remain. A pelitic and psammitic material, consisting mainly of fragments of spherulites of the matrix, was subject in these cases to recrystallization, and turned into an aggregate of small irregular grains of quartz and albite.

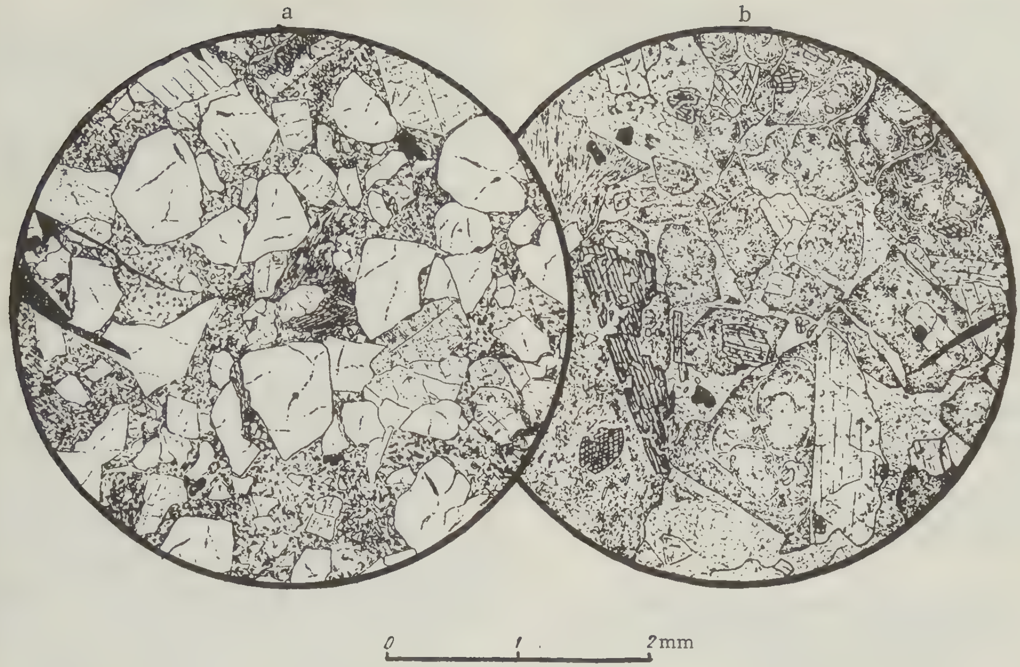

FIGURE 22. a) A crystalline tuff of quartz-keratophyre. Fragments of phenocrysts of quartz (white) and feldspar (dots). b) A lithoclastic tuff of hornblende porphyrite. Fragments of a felsitic matrix with traces of a perlitic structure in the lower part and phenocrysts of plagioclase and hornblende.

The boundary between the larger fragments and the [adjacent] material cementing them disappears. Traces of a perlitic separation are quite often observed in the larger fragments.

The crystalline tuffs of quartz keratophyres are less widespread than the preceding rocks. They now consist to two thirds of angular fragments of phenocrysts of quartz and feldspar, that are diverse in size (fig. 22a). The feldspar is usually albite, greatly argillized and speckled with small scales of sericite. Sometimes it is possible to recognize potash feldspar in the fragments. Between the fragments is encountered an argillaceous material with a relatively large quantity of chlorite.

Tuffs of quartz-keratophyres usually compose separate layers and seams in a mass of keratophyres. A tuffaceous material of this composition was not encountered in the cement of the agglomerates.

Tuffs of spilites and spilitic porphyrites

Fine clastic rocks of a basic composition are encountered in two thirds of all places. They are dense dark rocks, the fragmentary texture of which cannot be distinguished macroscopically.

Under a microscope it can be seen that these rocks consist of fragments of spilites and spilitic prophyrites in different ratios. The fragments of spilites are represented by small pieces of a matrix with variolitic, and more rarely with a microlitic texture. The fragments of spilitic porphyrites are represented by small pieces of a typical pilotaxitic or altered hyalopilitic matrix. Fragments of large grains of plagioclase and pyroxene are constantly encountered, but not in very large quantities.

Layered tuffs and tuffites

In many places in keratophyric agglomerates there are encountered layers of dense, clearly schistose rocks. The thickness of these strata is usually measured in centimeters, but from time to time it reaches 0.8 to 1.0 m. Some strata do not have a visible upper border and they are traced for an overall distance of several meters. Here the schistose tuffs change gradually into the massive tuffs and agglomerate lying on them. In other cases the strata are sharply distinguished among the agglomerates. The well-layered rocks composing them are usually darker, and the strata are traced for hundreds of meters even with an overall thickness of several centimeters.

The layering in the rocks here described shows up in the form of stripes, either darker and lighter or more or less dense. Under a microscope stratified tuffs that are not sharply distinguished have the same composition as

the tuffaceous cement of the agglomerates containing them. Our attention is attracted only by the exceptional constancy of the dimensions of the fragments (0.3 to 0.4 mm or 0.8 to 1.0 mm) and the orientation of the elongated fragments according to their platines. The fragments are usually represented by small pieces of a felsitic matrix that is also often cemented by calcite.

In sharply separated strata there are encountered rocks of a tuffaceous appearance, but apparently with a considerable quantity of a common clastic material. Here fragments of phenocrysts of quartz and albite prevail.

These rocks are apparently already related to tuffities which were deposited on the agglomerates during the short intervals of volcanic activity. They ought to be examined together with normal sedimentary rocks - siliceous shales and radiolarian jaspers, that are widely developed in the region.

SECTION III. THE PROBLEM OF THE SPILITE-KERATOPHYRE ROCK FORMATION

Chapter 7. The history and meaning of the spilite problem

The study of spilites just like that of certain other rock varieties begins with the work of English geologists at the end of the last century. The term "spilite" had appeared as far back as the pre-microscopic period of the development of petrology (Brongniart, 1827), but then it had only a textural meaning. Aphanitic varieties of altered greenstones of a diabasic composition were called spilites.

The English geologists, describing the volcanic rocks of southwest England, were first to use this term in the sense in which it is used today. Previous to that, attention had been drawn to the fact that spilites, in many respects similar to basalts, possess albite instead of basic plagioclase. Therefore spilites became considered a petrographic variety of basic extrusive rocks on a par with basalts, diabases, etc.

In 1911 Dewey and Flett [28] in a classic article not only distinctly defined these rocks in a petrographic sense, but also were first to consider their genesis. Their suggestion, that the spilites were formed as a result of autometamorphic processes, is now adhered to by the majority of geologists.

Dewey and Flett noted the association of the English spilites with other more silicic rocks and this permitted them to be the first to suggest the existence of a special spilite suite, comparable in significance to the "Atlantic" and "Pacific" series of rock families.

The furthest development of the spilite problem is found in the works of Wells [41]. While agreeing with the views of Dewey and Flett in relation to spilites, Wells gives much consideration to the silicic members of the spilitic formation, the keratophyres. The term "keratophyre" was first introduced by Gumbel in 1874 for intrusive rocks of an alkalic type. Later Lawson (1881) used this name for analogous rocks rich in sodium. Rosenbusch narrowed down the meaning of the term "keratophyre" still more by using it for palaeotypal extrusive rocks, rich in sodium and possessing the appearance of alkalic rocks, specifically rocks with an alkalic colored mineral. This definition of Rosenbusch entered textbooks of petrography, became widespread, and has been preserved to the present time. In Wells' work keratophyres were first defined as members of the spilite formation. From that time albitized normal extrusive rocks of silicic and intermediate composition have been called keratophyres. The genetic connection of the keratophyres or "sodium rhyolites" of Dewey and Flett with spilites has become clearer.

Later on, various petrographers touched on the problem of spilites. Benson [50, 51, 52, 53], describing the spilites of Australia noted that the alteration, considered a necessary property of these rocks, is absent in a few of them. It is impossible from a contemporary point of view to consider as substantiated the conclusion drawn by him from this about the crystallization of albite directly out of the melt, but it had a great significance for the further development of the spilite problem. N. Sundius, having at first (1915) considered the albite in spilites from Kiruna as having been formed as a result of regional metamorphism [92], adhered later (1930) to the opinion of Benson and attempted to substantiate what he had said [97]. From another side, P. Eskola in 1925 [81] adhered to the views of Dewey and Flett of the relatively metasomatic origin of albite, though he also denied a genetic connection between spilites and other rocks, i.e. the existence of a special spilitic formation.

Later (1938) in confirmation of his views Eskola made valuable experimental analyses on the albitization of basic plagioclase [156].

G. Beskow [101] and J. Gilluly [110] also hold to the same opinion on the metasomatic origin of albite, though in contrast to Dewey, Flett and Eskola, they do not consider albite to be of an autometamorphic formation. In Beskow's opinion, sea water seemed to be the source of sodium in regard to the extrusions of the spilites originated in under-water conditions. Gilluly connected the metamorphism to the intrusion of granites.

The fact that spilites occur as extrusive

rocks was established at the very beginning of their study. Benson and then Eskola introduced the notion "intrusive spilite" assuming layered beds and dikes of these rocks at a shallow depth.

In the work of Levinson-Lessing and E. K. Dyakonova-Savelyeva [60] there was first noticed the necessity of separating from the group of keratophyres the more basic rocks which are analogous to andesites of the normal lime-alkalic series. Descriptions of occurrences of albitization of plagioclase are also of interest in this work.

After the works of all these authors the significance of spilites was sufficiently appraised by European petrographers. But for a long time in America the existence of a special spilitic formation was not only not recognized, but it was even considered as unnecessary to separate spilites as a petrographic variety. R. Daly, Lewis, and other American petrographers identified the notion "spilite" and "changed basalt" ("metabasalt"). Only comparatively recently in American literature have there appeared works by authors who are beginning to hold the points of view of the Englishmen.

The work of Gilluly written in 1937 [110] is especially valuable. It is about the keratophyres of Oregon and, besides descriptions of these interesting rocks, discussions of the spilite problem of several years standing are summed up.

In this work the essence of the problem is defined. Gilluly considers that there are three main questions: 1) whether spilitic rocks appear to be derivative of a normal, calc-alkalic magma, as Daly, Sundius, (1915), Eskola and Beskow thought, or whether they were derived from special spilitic magma, which is in line with the views of Dewey, Flett, P. Geijer, R. Wells, H. Backlund and Sundius (1930); 2) whether the sodium-rich character of the rocks is determined by magma, as was thought by Dewey and Flett, Daly, Geijer, Wells, Backlund, Sundius (1930) and Eskola, or whether it was caused by outside factors, which is in line with the views of P. Termier, Sundius (1915), Beskow and of Gilluly himself; 3) whether albite was formed by way of crystallization out of the melt, as is maintained by Benson, Sundius (1930), and for more silicic rocks, by Dewey, Flett, Geijer, Wells, Beskov and Backlund, or whether it has arisen exclusively as a result of metasomatic substitution of another feldspar, agreed to by Daly, Sundius (1915), Eskola, and for more basic rocks, by others.

It follows from the definition of the spilite problem that it concurs partly with the problem of the albitization of plagioclase in extrusive rocks.

From the point of view of present-day petrography it is no longer enough to know whether the albite in spilitic rocks is primary or secondary and what is the source of sodium leading to its formation. It is necessary to ascertain, even if only partially, the physicochemical conditions of the process of albitization and the causes that give rise to it.

Albitization, just like many other postmagmatic processes is developed more widely in igneous rocks than is usually thought. Unfortunately, this process has still been studied little. Observations of rocks of spilitic-keratophyric formations can give a great deal of valuable material for elucidating it.

The question of the relation of spilitic rocks to rocks of a normal and alkalic series, and the question of the existence of a spilitic magma also have much significance in petrology.

Chapter 8. Review of the main spilite formations

A comparison of the spilite-keratophyre formation already studied, with other analogous formations of the world is necessary both for a basis of the names of the rock varieties used in this work, and also for an elucidation of the features of spilites in general. Only after examining all the factual material about spilites is it possible to resolve these or other questions of the spilite problem.

It is impossible to give a full summary on spilites. Not all the rocks described under the name "spilite" in the literature really appear as such, and, vice versa, not all real spilites are described under this name. This compels us to limit ourselves to the main and obvious spilitic formations of England, Australia, Fennoscandia, Crimea, Mugodzhar, and several other places.

The spilite-keratophyre formations of England

In England two independent spilite formations can be distinguished: 1) the world famous Ordovician (Cambro-Silurian) pillow lavas of southwest England and 2) the not very widespread Precambrian spilites. "Spilitic rocks" are also known among the basalts of Carboniferous age [148].

Precambrian spilites have not been examined separately in the literature, though in bedding conditions and petrographic features they differ from Ordovician spilites. They are developed only in the most western parts of England: on the island of Angelsey, the Lleyn peninsula (Caernavonshire) and in Pembrokeshire.

Together with the clastic volcanic rocks, quartzites and jaspers, they make up a so called monocomplex, lying on the oldest rocks

in England which are pencil gneisses.

The spilites are found in the form of pillow lavas, layers of which dip steeply or stand vertically. The pillow structure in them, however, has been well preserved, and only in places are the pillows deformed [14].

The petrographic description of the rocks is very short. It seems that the pyroxene is in great part altered. Pseudomorphs of olivine are completely absent. Variolitic varieties described in detail by C. A. Raisin [10] are widespread. These rocks are similar to the variolitic aphanites from the sheaths of the pillows of the pillow lavas of the Blyava. Tuffs of keratophyres are present, but they, like other silicic rocks, appear to be rare in the Precambrian of England.

In several places the spilites are greatly metamorphosed and turned into greenstone-type metamorphic schists, though generally in the Precambrian spilites of England metamorphism shows faintly, despite the greatly broken bedding of the layers.

Ordovician pillow lavas and the rocks accompanying them are widespread mainly in Cornwall, Devon, and Wales. Besides that, lower Paleozoic volcanic rocks are known on the east coast of Ireland and in some regions of Scotland. In this way the area of distribution of the formation that interests us is rather extensive.

The conditions of the bedding of the rocks is different in different places, but in the majority of cases layers are found in a relatively weakly interrupted [transgressing] bedding, forming gently sloping folds. It is sometimes possible to see almost horizontally lying pillows of lava exactly the same as on the Blyava.

In some regions of Wales [43] pillow lavas are also encountered in interrupted [transgressing] bedding, with an angle of dip up to 50°.

The stratigraphic section of the volcanic beds in various places is also variable. Extrusive and fragmentary volcanic rocks are inter-bedded with siliceous shales, radiolarian jaspers, graptolitic shales and other normal sediments.

The beginning of the volcanic activity took place in north Wales in Tremadoc, and later in more southerly regions. The upper boundary of the volcanic rocks is different in different places. In comparison with the spilites of the Blyava the rocks of England here described are not much older.

The underwater character of extrusion of a large part of the English spilites is doubtless, being indicated by the layers of radiolarian jaspers and other marine deposits. However, a land formation is assumed for the volcanic complex of Skomer in Wales [30]. Opinions differ with respect to the depth of the sea basin; in England as also on the Blyava there are no definite marks that indicate its depth.

In several regions of Wales there are basic and ultrabasic rocks intruded into the mass of volcanic rocks, that are also observed on the Blyava.

The pillow lavas of England are morphologically identical to the pillow lavas of the Blyava. Here were also observed both large (up to 1.0 to 1.5 m) and small (0.15 to 0.30 m) pillows with a different degree of separation. Here and there are gradual transitions of pillow lavas into agglomerates or so called "spilitic breccias", in which separate pillows are found in tuffaceous cement.

The pillow lavas are formed by the spilites prevailing among the rocks of the formation being examined. Keratophyres are known in many places, and clastic-volcanic rocks of a keratophyric composition ("volcanic breccias") are especially widespread. Sometimes these rocks together with keratophyres even predominate over the spilites.

The petrographic description of the rocks of the formation being considered is not complete enough in the literature. Several types of spilites exist. Rocks with brownish pyroxene and "subvariolitic" textures are known. They correspond to the spilites from the neighborhood of the Blyavinsky deposit. The pyroxene in the Ordovician spilites of England is more or less preserved. Pseudomorphs after olivine also occur. The plagioclase in a large part of the rocks is albite. Diabases with basic plagioclase, that associate with typical spilites, are described in only a few of the most recent works. In the old works of Dewey and Flett, and Wells such an association was denied. Among the spilites of Ayreshire non-albitized rocks are encountered in fragments of agglomerates. Here they are considered as rocks out of which spilites ("pre-spilite") were formed. Rocks of an intermediate composition are not mentioned in the literature, but judging from chemical analyses (see fig. 28) and some descriptions, such rocks are to be found here.

The keratophyres of England are scarely described in the literature. In the old works they are in large part called rhyolites, sodium felsites and so on. On the whole the Ordovician spilitic-keratophyric formation resembles the formation of the Blyava more than any other.

The spilites and keratophyres of Australia

In Australia the rocks that interest us are known in the northeastern part of New South

Wales, 400 km north of Sidney. They are found in a suite of siliceous shales, radiolarian jaspers and coralline limestones of middle Devonian age. This suite together with other Paleozoic deposits lying conformably on it is gathered into folds. Ultrabasic and basic rocks of the middle Carboniferous age intrude the folded complex.

Here pillow lavas are widespread, just as on the Blyava and in England. Sometimes separate pillows or several pillows are contained in the mass of a siliceous shale. Benson [50] considers such pillow lavas as layer intrusions into hardened sea silt. It is possible that this is so, but also the possibility is not excluded of a simultaneous formation of the lava and of the siliceous material. A part of the spilites and the more silicic rocks are found in the form of covers and dikes, but there are no data given about their dimensions and shapes. Pillow structure was observed in several dikes of spilite.

The presence of coralline limestone in the spilites of Australia indicates the shallow conditions of their extrusion.

Tuffs and other clastic volcanic rocks are not very widespread.

Among the extrusive rocks dolerites, spilites, variolites, keratophyres, and magnetite keratophyres are distinguished. The basic rocks can hardly be distinguished from the spilites of the Blyava. They consist of plagioclase, monoclinic pyroxene, and chloritic mesostasis. The plagioclase is usually fully albitized. Benson defined it as oligoclase but this definition needs verification. Basic plagioclase was observed in one case. The pyroxene is sometimes fresh, sometimes partially altered to chlorite, epidote and uralite. There were observed pseudomorphs after olivine and a serpentine-like mineral ("bowlingite"). In several dolerites the interstices are filled with quartz and micropegmatite. In the amygdules, axinite is encountered besides the common minerals, i. e. chlorite, quartz, and calcite.

The variolites of Australia are similar to analogous rocks of the Blyava and Yalgooba. Usually they are variolitic aphanites, but there are also real variolites with varioles and an intervariolic mass.

Many varieties exist among the keratophyres. Some of them are doubtlessly related to rocks of an intermediate composition and correspond to the spilitic porphyrites of the Blyava. They have a pilotaxitic matrix and phenocrysts of albite and pyroxene. In others there is a lot of quartz in the matrix. Of the keratophyres of the Blyava the varieties with a pilotaxitic micropoikilitic matrix resemble them. Some Australian keratophyres are enriched with magnetite. This is apparently connected with processes of oxidation of lavas and does not have the significance that Benson [52] gives it.

Clastic volcanic rocks consist mainly of clastic keratophyres.

The volcanic rocks of the Karadag Mountain in the Crimea

This spilite-keratophyre formation is similarly described by Levinson-Lessing and Dyakonova-Savelyeva [60]. For a comparison with the spilites of the Blyava we may confine ourselves to its main features. In contrast to the majority of spilite formations the volcanic rocks of Keradag are comparatively young. The volcanic activity begins at the end of the middle Jurassic era and continues to the end of the upper Jurassic.

Spilitic rocks are encountered together with younger liparites and basalts. The geological independence of these two formations is established. Layers of spilitic rocks are found in greatly broken bedding, and the strata have a steep dip, being sometimes vertical. Liparites and basalts form dikes and necks, cutting the spilites and keratophyres, and sometimes inconsistently overlap the latter.

Such an association of spilites with normal rocks is interesting for elucidating the independence of spilitic formations in general.

The shapes of the extrusive bodies of the spilitic rocks on the Karadag were better preserved than on the Blyava. The spilites are found chiefly in the form of typical globular lavas. The more silicic rocks form separate flows, dikes and necks. Extruded rocks are accompanied by a large quantity of agglomerates, tuffs, tuffites, and argillaceous shales. Marine fauna was found in the agglomerates of the Karadag.

Volcanic eruptions apparently originated in underwater conditions in the same way as on the Blyava and in other regions where spilites are widespread.

The petrographic description of the volcanic rocks of the Karadag appears to be the best of all descriptions of spilites and keratophyres. Typical spilites here have a subordinate significance. Besides that, many rocks, called spilites by Levinson-Lessing and Dyakonova-Savelyeva, are similar to the spilitic porphyrites of the Blyava. Chemical analyses of these rocks show that they are really more silicic than typical spilites.

Rocks of an intermediate composition on the Karadag predominate over the remainder and in this lies the main difference between the examined and others, including to some extent, the formation of the Blyava. To

these rocks ought to be related those which Levinson-Lessing called keratospilites, and a large part of the keratophyres (so called keratophyrites).

They all have a porphyritic texture with a pilotaxitic ("trachytic") matrix, in which the glass is fully converted into an aggregate of chloritic minerals. The plagioclase in the phenocrysts is sometimes partially albitized ("spotted feldspars"), the albitization taking over mainly the central parts of the phenocrysts. Therefore borders of labradorite were sometimes observed around the albite. Exactly the same phenomena were also observed in the rocks of the Blyava (fig. 19).

Chloritization of the phenocrysts of plagioclase is also characteristic. The pyroxene forms occasional phenocrysts.

Levinson-Lessing calls the silicic rocks of the formation here examined oxikeratophyres. In composition they are close to quartz-keratophyres, but surplus silica is found in them not in the form of phenocrysts of quartz but in the matrix. It is apparently as difficult to distinguish real keratophyres from these rocks and from rocks of an intermediate composition on the Karadag as it is on the Blyava. Real quartz-keratophyres on the Karadag are rare, but we know of no analogous rocks on the Blyava.

The matrix of the keratophyres of the Karadag has a felsitic and sometimes a pilotaxitic texture (paleotrachytoidal appearance of the matrix). Spherulitic textures that are widespread on the Blyava are unknown here.

In the phenocrysts is found turbid (brownish) albite which is, however, considered to be primary. Spotted feldspars are also encountered i. e. partially albitized plagioclase and potash feldspar [60, page 52]. The latter is sometimes observed in phenocrysts, sometimes it shows up only in a higher content of potash in the chemical composition of the rock. These are the so called paleoliparites of the Karadag.

The formation which has been considered is developed not only on the Karadag Mountain; it is also possible to encounter analogous rocks on the western part of the south shore of the Crimea in the regions of cape Fiolent, Limen, and others. But here these rocks have been little studied and a comparison of them with the spilites of the Blyava offers nothing new.

The spilite-keratophyre formation of the Mugodzhar

This formation has been studied in detail in the course of the last few years by A. A. Chumakov [66, 67, 68, 69]. The final results of his analyses have not yet been published, but the features of the formation are already clear from the preliminary reports.

The age of the Mugodzhar spilites has been determined as lower and upper Silurian; the keratophyres have already been related to the lower and mid-Devonian. Chumakov [68] allows some interval between the formation of the spilites and the keratophyres, during which gabbro-diorites and plagiogranites were intruded. However, proofs that these intrusive rocks are older than the keratophyres are not offered in his works [66, 67, 68, 69]. There are only indications that some gabbros (according to Chumakov-another Embinsky type) are younger than keratophyres. Thus, it is possible that the rocks of the spilitic formation in the Mugodzhar are related to basic intrusive rocks as was the case on the Blyava. Intrusions of ultra-basic rocks are unknown in the Mugodzhars.

The stratigraphic section of the sequence of volcanic rocks is the same as that on the Blyava, i. e. the basic rocks compose lower horizons, but intermediate and silicic rocks are found in the upper ones. The volcanic rocks are interbedded with radiolarian jaspers and siliceous and graptolitic shales.

The bedding of the rocks in the Mugodzhars is more broken than on the Blyava. The usual angle of dip is 50 to 70°. In places the spilites are sheared.

Typical pillow lavas with detached pillows are very widespread. Between the pillows, a tuffaceous or siliceous mass is sometimes found. The separate pillows have concentric variolitic and bubbly zones, the central part of the pillows being more porous than the pillow lavas of the Blyava.

There are many textural varieties among the spilites from medium-grained diabases to glasses. The variolites and glassy varieties are more widespread in the Mugodzhars than on the Blyava. Complete horizons of glassy rocks, more than 1 m thick, are known. It is characteristic that the glass in some places has been well preserved and differs little in appearance from very recent basaltic glasses [69]. A chemical analysis of Mugodzhar glass shows that it also has a basaltic composition, i. e. it has not undergone albitization.

Transitions of spilites into unalbitized rocks are observed as often as on the Blyava. Remains of labradorite in laths of albite are also known.

Uralitic hornblende is encountered in several spilites, formed in place of pyroxene and glass.

The Mugodzhar porphyrites sometimes consist of spilites with porphyritic formations of pyroxene, but in great part these are rocks of an intermediate composition corresponding to

the spilitic porphyrites of the Blyava. Albite is common in the phenocrysts and sometimes zoned andesine is encountered.

The silicic rocks of the Mugodzhar are quartz-keratophyres (quartz-porphyrites, albitophyres and orthophyres). The quartz keratophyres are the same as on the Blyava. The matrix in them is either felsitic or spherulitic. There is a spherulitic border around the phenocrysts of quartz [66, table XII]. Micropegmatitic phenocrysts are also encountered [66, table X].

"Albitophyres" have a felsitic and an andesitic or pilotaxitic matrix. Potash feldspar is sometimes encountered in the phenocrysts.

Clastic-volcanic rocks in the Mugodzhar are less widespread than on the Blyava.

On the whole the spilitic rocks of the Mugodzhar are similar to the spilites and keratophyres of the Blyava. It is possible that these are rocks of a single formation since, by tracing the distribution of spilites to the south of the Blyava, we move directly into a region where Mugodzhar spilites occur.

The spilites of Karelia and the Kola Peninsula

The greenstone varieties in Karelia occupy a wide area on the northwest shore of Lake Onega in the region of Segozero, near the village of Nadvoitsa, Shuozero and to the east of Ukhta. On the Kola Peninsula they form a belt from Lake Imandor to the southeast as far as the upper reaches of the Varzuga river.

All these rocks make up a single formation of the Proterozoic era. In the opinion of V. M. Timofeyev [86] this formation occurred in two cycles. The rocks of the northern regions of Karelia and the Kola Peninsula are the older ones ("a Segozero-Nadvoitsa complex"); the rocks on the shore of Lake Onega ("a Suisar complex") are the younger ones.

The conditions of the bedding and the stratigraphic section of the layers of the volcanic rocks are different in different places. In the neighborhood of Sevozyero, Nadvoitsa and in other more northerly regions the layers have been subject to intensive folding. On the shore of Lake Onyega it is possible to encounter them in a faintly broken seam.

The prevailing occurrence of the intrusive bodies appears to be as pillow lavas, indicating the under-water character of the extrusions. Thick flows are also encountered. Pillow lavas were observed in a perfectly preserved shape by Timofeyev [79, 86] on the island of Suisar. Morphologically they do not differ from the pillow lavas of the Blyava. The same dependence of the shape of the pillows on their dimensions is here observed: the pillows which are less than 1 m in diameter are almost spherical, the larger ones have an ellipsoidal shape. The pillows here are even more separated than on the Blyava. A tuffaceous material is deposited between the pillows, or holes are observed with stalactites of chalcedony. The peripheral parts of the pillows consist of a less crystalline rock (variolitic zones). In those cases where a tuffaceous material is found between the pillows, the variolitic zones are very broad, but where the tuffaceous mass is absent, a thin glassy shell is observed instead of these zones. Timofeyev explains this by a more uniform cooling of the lava in the tuffs than in water. Some pillows have in their center large (up to 0. 3 m) holes. Pillow lavas are found near Nadvoitsa in a greatly changed state. Here layers of pillow lavas are vertical, and the pillows are compressed and altered into plates several centimeters thick. It is now impossible to compare such "pillow" lavas with the spilites of the Blyava, but they are similar to the pillow lavas of the Precambrian spilites of England.

The usual lava flows were preserved on the shore of Lake Onega [78].

The extrusive rocks of Karelia and the Kola Peninsula are interbedded with clastic-volcanic and sedimentary, partially metamorphozed rocks. These are mainly tuffs, sandstones, quartzites and sericite schists.

In many places the volcanic rocks have been subjected to strong dynamo-thermal metamorphism. The spilites of Segozero, Nadboitsa and other northern regions have not preserved their original appearance and are often converted into green schists or amphibolitic, epidotilic, or other metamorphic rocks. This prevents a comparison with the spilites of the Blyava. Even in the most preserved spilites of Segozero various processes of secondary alterations are widely developed: epidotization, complete or partial uralitization of pyroxene, the forming of crystalloblastic textures and so on, which is not observed at all in the rocks of the Blyava.

The spilites from the shore of Lake Onega are less altered. They are represented by numerous textural varieties -"diabases", "aphanites","augite porphyrites", amygdules, variolites and so on. All the varieties consist of monoclinic pyroxene, albite, and chlorite, but in contrast to the spilites of the Blyava, uralite is often present in their matrix in several diabases, the plagioclase is not albitized. The pyroxene is sometimes colorless, sometimes brownish with $2V = +50^{\circ}$.

There are more textural varieties of spilites in Karelia than on the Blyava. The rocks with a porphyritic texture ("augite prophyrites") are

very widespread. Besides pyroxene there are encountered in the phenocrysts pseudomorphs after olivine. In amygdaloidal rocks the amygdules are filled by calcite, quartz, and chlorite, and in some Suisar spilites by chalcedony and shungite.

The variolites that are widespread in Karelia have become world famous [72]. As has been noted, they hardly differ from the variolites from the neighborhood of Usergan in the Blyavinsky region. Here there are fewer real variolites, i. e. rocks with varioles and an intervariolitic mass, the same as on the Blyava, than variolitic aphanites. The conditions of the bedding of the variolites in Karelia are diverse. In the region of Yalguba they compose independent bodies, and on the island of Suisar they form only peripheral zones of pillows of the lavas [86].

The spilitic rocks of a more silicic composition are almost absent in Karelia. Some feldspathic porphyrites can be compared with the spilitic porphyrites of the Blyava and the keratospilites of the Karadag. Keratophyres are known only among the dynamo-metamorphosed rocks of the Nadvoitsa region [85].

Clastic-volcanic rocks of Karelia differ from analogous rocks of the Blyava mainly in their composition. They are tuffs and agglomerates of spilites that are more or less altered. Among them is the well known "solomon-breccia" that has been described by many petrographers.

On the whole there are many general features in the spilites of Karelia and the Blyava, but there are also differences caused by their different ages and different geological conditions.

The spilite-keratophyre formations of the Scandinavian Peninsula

In Scandinavia two spilitic formations can be distinguished: 1) Precambrian keratophyres and spilites in the region of Kiruna [90-94, 96-97] and 2) Lower Paleozoic volcanic rocks in the region of Trondheim [98-100] and in south Lapland [101].

The Precambrian spilitic rocks are mainly represented by silicic varieties. In the literature these rocks are described as "syenite-porphyrites", "quartz-containing porphyrites", "albitophyres" and so on, but it is certain that they belong to keratophyres and quartz keratophyres. They make up the large (in thickness, several hundred metres) upper part of the mass of volcanic rocks, the lower horizons of which consist of spilites, albitic porphyrites, agglomerates and tuffs of a basic to intermediate composition.

The volcanic rocks are found in greatly disturbed beds and have been subject to significant dynamo-thermal metamorphism. The keratophyres and their tuffs are often turned into so-called leptites, and the spilites change into amphibolites and other metamorphic rocks similar in composition. A strong development of regional metamorphism appears to be the main feature of the spilitic rocks of Kiruna distinguishing them from the spilites of the Blyava, and giving them a resemblance to the spilites of the northern regions of Karelia.

The extrusive shapes of the bedding were not preserved in the majority of cases, but here too a wide development of pillow lavas is characteristic of the spilites.

The sedimentary rocks accompanying the spilites are represented by jaspers and, here and there, by limestones.

The petrographic features of the spilites of Kiruna are partially conditioned by regional metamorphism. The main component parts appear to be albite and uralitic hornblende, formed of pyroxene and perhaps chlorite. The plagioclase is not always albitized in the spilites and is represented by labradorite in some pillow lavas. The texture of these rocks, as can be seen from microphotographs introduced in the works of Sundius [92] and Geijer [96], resembles the hyalo-ophitic texture of the spilites from the neighborhood of the Blyavinsky deposit. Here very elongated laths of plagioclase are also characteristic.

In rocks of an intermediate composition the chlorite is also replaced by uralite, and, besides that, biotite is widely developed. In respect to the general appearance of the rocks under a microscope, "the albitic porphyrites" and some "magnetic syenite-porphyrites" greatly resemble the spilitic porphyrites of the Blyava.

A feature of the porphyrites of Kiruna appears to be the relatively weak evidence of albitization. Here potash feldspar is often encountered, only partially albitized or completely unalbitized. Magnetite is found in great quantity. Geijer gave this great significance. Holding to Fenner's views, he considered rocks rich in magnetite the last products of crystallization-differentiation. However, it is more probable that the formation of magnetite in the keratophyres of Kiruna is not connected with their primary crystallization.

With regard to texture the rocks here described are different from the keratophyres of the Blyava. Spherulitic textures are absent here, but micropoikilitic textures are developed, and also others, caused by a re-crystallization in the solid state.

On the whole the Precambrian spilitic rocks of Scandinavia differ strongly from the spilites of the Blyava. They are more similar to the spilites of Karelia, and, perhaps, with them constitute a single formation. The greenstones of Finland are also part of this formation, but they have not been greatly studied [95].

The lower Paleozoic spilites of Scandinavia apparently form a single unit with the Ordovician spilites of England, but volcanic activity occurred here a little later, mainly in the lower and partly in the upper Silurian period.

The spilites form typical pillow lavas, indicating under water conditions of extrusion. With the spilites are found their tuffs, siliceous shales and jaspers. Siliceous rocks are sometimes observed between the pillows of these lavas.

The volcanic rocks occur in irregular layers and in places they have been subject to dynamothermal metamorphism. In many places ultrabasic and basic rocks have intruded them, as was the case on the Blyava, in England, and in Australia. Besides that, numerous deposits of pyrites (Ryoros, Sulitelma and others) are found among the Norwegian spilites which especially brings them nearer to the rocks of the Blyava.

From a petrographic description of the spilites being considered it can be seen that they resemble the spilites of the Blyava. Variolites and varieties with subvariolitic textures are widespread in the region of Trondheim. In south Lapland pillow lavas are formed from spilites with porphyritic phenocrysts of uralitized pyroxene ("uralitic porphyrites"). The uralitization and epidotization of these rocks is apparently due to regional metamorphism. Sometimes they even change into amphibolites and metamorphic schists which are near to them.

Keratophyres and quartz keratophyres are more widespread in south Lapland than in the region of Trondheim. In contrast to the keratophyres of the Blyava they have textures caused by secondary re-crystallization. Biotite appears to be the usual mineral.

The tuffs of the spilites in south Lapland represent greatly altered uralitized rocks. Here the keratophyric tuffs and agglomerates are sheared

The spilites and keratophyres in North America

Several spilite formations exist in North America, but in the literature there is little information about them. In the region of the Great Lakes and the adjoining provinces of Canada a Precambrian spilitic formation is developed [102-107]. Lower Paleozoic spilites are known in Newfoundland and New Brunswick [108, 109]. Keratophyres and spilites of the Permian age in Oregon have been well studied [110]. Mesozoic rocks of this type are encountered in California [111, 113] and in Alaska [112].

Tiassic and Tertiary keratophyres in the state of Nevada are referred to, but they are connected with the trachytes and apparently are not related to the group of spilitic rocks.

Precambrian spilites form the lowest horizons in the stratigraphic section of the Archean rocks of the Canadian shield (Keewatin series). They are interbedded with siliceous shales and jaspers containing the well-known iron-ore deposits of the Great Lakes.

The volcanic rocks have been subjected to intense folding and in many places have been converted into greenstone metamorphic schists. Where shearing appeared to be weaker the pillow form of lavas prevails. This permitted American geologists to consider volcanic rocks as the result of underwater extrusions and to connect with these extrusions the formation of iron-ore deposits [104]. Pillow lavas from the region of the Great Lakes differ from the pillow lavas of the Blyava and many other places in that in great part they have become deformed, just like the Precambrian spilites of England, Kiruna, and north Karelia.

Petrographic descriptions of the rocks here considered are very short. There apparently exist many textural varieties including amygdules, variolites and plagioclasic porphyrites. Mineralogically an important role is played by uralite, epidote, and other secondary minerals. Pyroxene is sometimes present, but it was not preserved in the najority of cases. Muscovite is referred to in many descriptions. The composition of the plagioclase is not usually determined. C. Van Hise points to the presence of labradorite in these rocks (Ely green-stones). Not many have apparently noted the albitization of plagioclase [106].

Silicic and intermediate rocks are little developed in this formation and are hardly described. Clastic-volcanic rocks, represented by volcanic breccias of a spilitic composition and by tuffs are greatly altered and have lost their original appearance.

On the whole the Precambrian spilites of North America differ from the spilites of the Blyava and can be compared only with the Precambrian rocks of England, Karelia, and Scandinavia.

The lower Paleozoic spilites in New Brunswick together with keratophyres, tuffs, and tuffogenic sediments form a mass several

thousand meters thick. They are found in broken bedding and are partially dynamo-metamorphosed. The spilites, and to a lesser degree keratophyres and tuffs, are in contact with metamorphic schists. The age of these rocks is obscure. Flaherty relates them to the Precambrian, but without sufficient grounds. The variolites, apparently from the same formation in Newfoundland, are related by Daly to Cambrian.

Rocks that are called spilites in New Brunswick are somewhat more silicic than the typical spilites of the Blyava and other places. They almost always have a porphyritic texture, though subvariolitic varieties are also mentioned. The pyroxene is usually fully replaced by chlorite and uralite. Pillow structure was not observed in these lavas.

The variolites of Newfoundland and the aphanites accompanying them represent typical spilites and have the appearance of pillow lavas.

Among the keratophyres of New Brunswick there exist quartz-keratophyres with spherulitic textures and other rocks very similar to the keratophyres of the Blyava.

The keratophyres of Oregon together with spilites subordinate to them, "meta-andesites", tuffs, jaspers, conglomerates, and limestones with Permian fauna form a mass also more than a thousand meters thick. The bedding of the rocks is greatly broken, and the layers dip steeply or are vertical.

The most widespread variety of the keratophyres appears to be quartz keratophyres with a felsitic or spherulitic matrix. In the latter case the phenocrysts of quartz are surrounded by a spherulitic border. Micropegmatitic accretions of phenocrysts of quartz and feldspar were also observed. Partially albitized potash feldspar is sometimes found instead of albite.

The quartz-free keratophyres of Oregon have a more basic composition, and some of them can be compared to the spilitic porphyrites of the Blyava. The matrix in them is andesitic or "felted". Besides albitized plagioclase, there is found in the phenocrysts pyroxene that has been partially replaced by chlorite, uralite, and brown hornblende.

In several rocks beside the usual albitization of plagioclase, are also observed veins of hydrothermal albite. The plagioclase in the phenocrysts is sometimes only partially albitized, as is also the case in some rocks of the Blyava. Such rocks in Oregon appear to be intermediate between keratophyres and "meta-andesites". The latter differ from keratophyres only in the composition of plagioclase and are considered as rocks from which the keratophyres were formed. In this respect they are analogous to the hornblende porphyrites of the Blyava.

In the amygdules of the spilites of Oregon, hydrothermal albite was observed together with quartz, chlorite, and epidote.

Several varieties exist among the spilites from microlitic rocks to "albite diabases".

Clastic-volcanic rocks, mainly "breccias of keratophyres" are very widespread in Oregon.

Mesozoic greenstone rocks in California compose the Mother Lode gold-ore zone, where they are found in greatly broken bedding and in places sheared. Here pillow lavas of spilites ("augite basalts"), keratophyres, tuffs, and volcanic breccias are well-known. The keratophyres have a more basic composition than on the Blyava, and correspond to spilitic porphyrites. In the andesitic matrix of these rocks are found phenocrysts of albite and pyroxene.

On the north shore of San Francisco Bay (Point Bonita) the spilites are found in less broken bedding. Typical pillow lavas are formed from rocks similar to the microlitic varieties of the spilites of the Blyava. There are also encountered subvariolitic varieties, analogous to the spilites of the neighborhood of the Blyavinsky deposit.

The pyroxene preserved in more crystalline rocks ("diabases") is somewhat colored. An iddingsite-like mineral forms pseudomorphs after olivine. The composition of the plagioclase has not been studied, and sometimes is incorrectly defined as labradorite according to the angle of extinction of 17^{o}. Variolites and variolitic aphanites are also widespread in this region. They do not differ from analogous rocks of the Blyava, Yalguba and Durance.

In Alaska typical pillow lavas of Jurassic spilites are well-known in the region of copper deposits. Only morphological descriptions of them are encountered in the literature.

Spilites and keratophyres of other districts

Besides the formations considered there are mentioned in the literature numerous cases where spilites and keratophyres occur, but it is not always possible to establish whether they are real spilitic rocks.

In the U. S. S. R. besides the regions earlier indicated, greenstone varieties are known in the Caucasus [118-121], Novaya Zemlya [122-125], on the eastern slope of the Urals [126], in Kazakhstan [128-129], in Middle Asia, and on the Altai [130].

It is possible that the "albitic diabases" of the Caucasus do not appear like spilites, but,

on Novaya Zemlya, in the Urals, and in the Altai, such rocks undoubtedly exist. The spilites of the eastern slope of the Urals constitute a single formation with the rocks of the Blyava.

In Europe there exists extensive literature on the keratophyres and diabases of Germany. The majority of these rocks do not appear like spilites and keratophyres. Analyses of H. Gotz [150] showed that in the "keratophyres of the Lahn river valley there is found an alkalic colored mineral and pseudomorphs after nepheline" i. e. that these rocks are related to an alkalic series. An alkalic character is observed also in diabases of the Harz and Fichtelgebirge. It is not impossible that several of them do appear like spilites, just like the rocks of Czechoslovakia [146], Greece [141] and France [131, 135].

Chapter 9. Petrochemistry of spilite-keratophyre formations

Features of the chemical composition of spilites and keratophyres in general

The chemical compostion of the individual members of the spilite-keratophyre formations has long attracted attention. The analyses of spilites have been compared with the analyses of basalts, and it is seen from a comparison of the figures that the spilites are characterized by a higher content of Na_2O, Fe_2O_3 (and FeO) and a lower content of K_2O, CaO and MgO. The high content of sodium and its prevalence over potash and lime is evident from the mineralogical composition of the rocks, but the higher ratio of Fe:Mg, and also the higher content of TiO_2 and CO_2 can be recognized only after a comparison of the analyses.

These features of the composition of spilites were first noticed by Wells [41], who compared several analyses available at that time, ascertained from them the average composition of these rocks and compared it with the average composition of basalts. Later Sundius [97] amplified the comparison of the chemical composition of spilites with several new analyses and obtained a new average composition, which differs little from the first one. In comparison with basalts this "average spilite" is also characterized by the same features.

The chemical composition of the keratophyres has been studied still less. It can be seen from the mineralogical composition that the prevalence of Na_2O over K_2O is also characteristic for these rocks. The comparisons carried out by various authors of analyses of keratophyres and rhyolites have confirmed this.

The inference of the average composition of the separate members of the spilite-keratophyre formations and their comparison with the average compositions of rocks of a normal rhyolite-basaltic series is not a correct method of study of the chemical composition of these rocks. At the present time there is only a small number of analyses of spilites and keratophyres, and therefore every analysis of a rock, by chance incorrectly determined or atypical, can greatly distort a truly average or typical composition. A comparison ought to be carried out not between average types, but between unit complexes of the rocks. The most convenient method for such a comparison was worked out by Zavaritsky [165, 166, 167]. It consists of the construction, by a defined method, of a diagram of the chemical compositions of rocks and of an analysis of those regularities which are represented in this diagram.

Almost all the analyses of these rocks have been collected from the literature for the study of the chemical composition of spilites and keratophyres. For this, analyses are taken of all rocks connected geologically with one or another spilite-keratophyre formation, irrespective of whether they were defined as spilites and keratophyres, or as "diabases", "metabasalts", "felsites", "sodium rhyolites" and so on. Such rocks turned out to be mainly the spilites of England, the Crimea, Moogodzar, Karelia, Australia, and the rocks of the Blyava and others described in this work. In the majority of cases the analyses that were rejected were of individual spilites, metabasalts and keratophyres, not connected with some established spilite-keratophyre formation. Many of these rocks are undoubtedly related to basaltic formations and appear to be only chance deviations. It is impossible to unite them with real spilites as was done by H. Fairbairn [155]. Such a union is arbitrary; it does not reflect natural geological associations, and prevents an elucidation of the differences between spilites and basalts.

The analyses that have been collected were converted into various characteristics according to Zavaritsky and a petrochemical diagram of these data was set up (fig. 23).

From an examination of the diagram the following conclusions may be made:

1) In their chemical compositions all the members of the spilite-keratophyre formations differ from the rocks of a normal rhyolite-basaltic series. A large part of their figurative points do not lie on the line of a normal series. The position of the latter is exactly defined, since it goes through the average types of basalt, andesite and rhyolite, and essentially represents the sum total of figurative points of an endless number of analyses of rocks of a normal series.

2) The chemical composition of different rocks

of spilite-keratophyre formations varies within wide limits. This is expressed in the diagram in that the figurative points are more or less scattered. Separate rocks have a composition not only of normal basalts and andesites, but also of typical rocks completely opposite to spilites, namely of calci-basalts and calci-andesites.

3) The spilites and keratophyres form an uninterrupted series of rocks, analogous to a normal rhyolite-basalt series. The points on

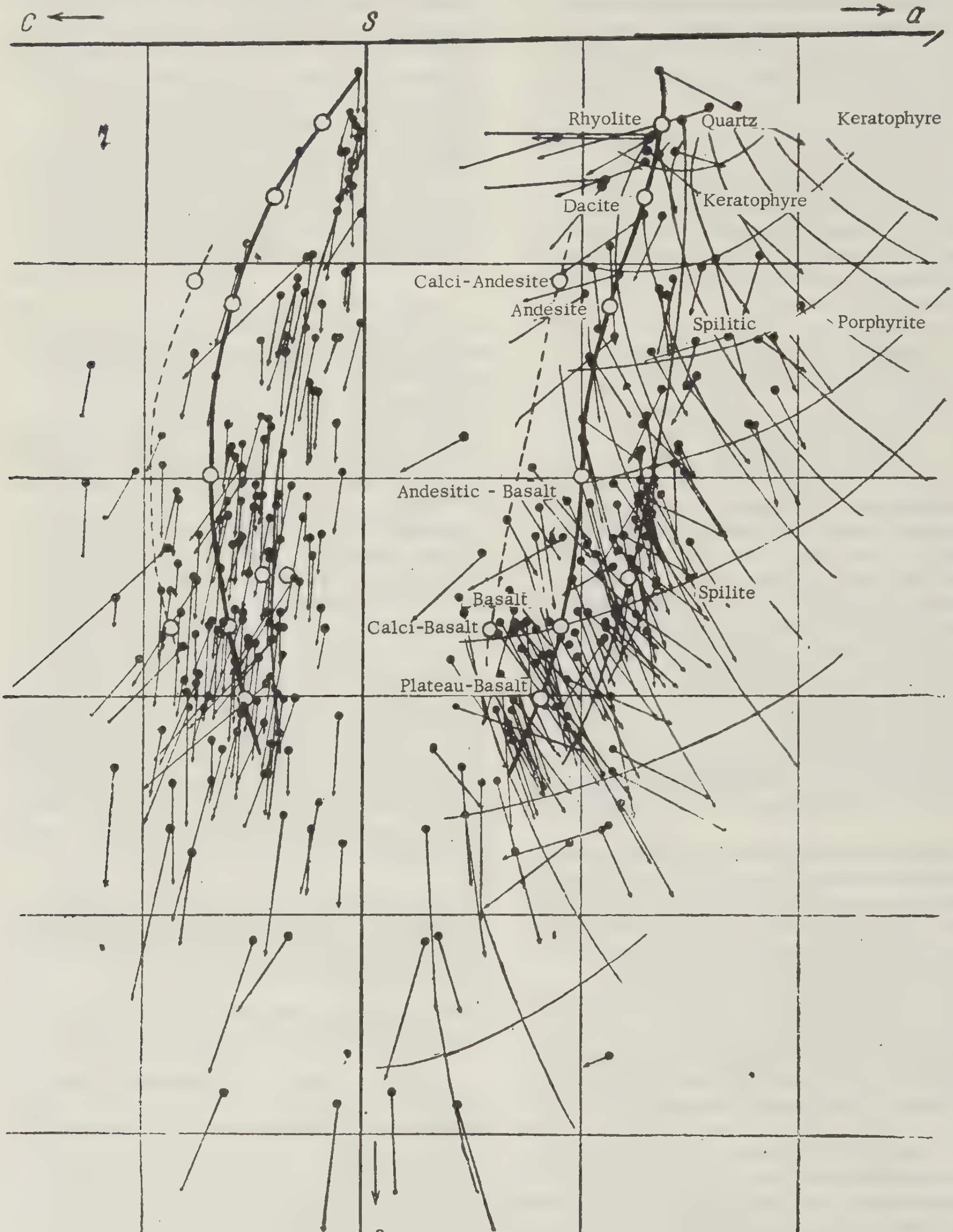

FIGURE 23. The chemical composition of rocks of spilite-keratophyre formations. For comparison there are marked the average compositions of rocks of a normal series according to Daly [165], and the average composition of a spilite according to Wells [41] and Sundius [97], with a little lower value. There are also marked the lines conveying the regularity of the change of direction and the magnitudes of the vectors on a plane asb, depending on the position of the figurative points according to Zavaritsky [166].

the diagram are located inside an uninterrupted belt along some line parallel to the line of the normal series.

4) In comparison with the rocks of a normal series all members of spilite-keratophyre formations are characterized by:

a. A higher content of alkalis (a) in the diagram projections of the figurative points on a plane asb are more remote from the line sb than the projections of the line of a normal series. In the most silica rich rocks, the quartz keratophyres, this feature is absent.

b. A significant and constant prevalence of Na_2O over K_2O in the diagram the vectors are on the csb-plane, conveying the correlation of these oxides, pointing almost directly downwards.

c. A lower content of feldspathic lime (c) the projections of points on the csb-plane drawn closer to the line sb, than a projection of the line of a normal series. This feature is apparently least important and is absent in several spilites. [There is no point d. Ed.].

e. Other features of the composition of spilites do not find a sufficiently obvious reflection in the petrochemical diagram. A ratio of Fe:Mg, higher than in basalts ought to convey somewhat shorter vectors on the asb-plane; in Figure 24 this is shown in another form. A higher content of TiO_2 and CO_2 cannot generally find its reflection in the diagram. This feature is also shown in Figure 24.

f. Between the spilites and the basalts there apparently exist continous transitions, judging from the fact that in the diagram the belt of figurative points comes into contact with the line of a normal series. This has already been noticed by Faïrbairn [155] and Gilluly [110] while considering a triangular diagram of normative feldspars. Such a diagram is represented in Figure 25.

g. The parallelism between a normal series and a series of spilitic rocks permits us to look into the systematization. It is perfectly evident from the diagram that rocks with approximately the same content of femic components (b) as in basalts, ought to be called spilites. Spilitic porphyrites (keratospilites) in this respect ought to correspond to andesite, keratophyres to dacites, and quartz-keratophyres to rhyolites. However, as we will see below, the definitions of the rocks by various authors do not always correspond to the position of the figurative points.

A comparison of the spilite-keratophyre formation of the Blyava with several others

Having clarified the petrological features of spilites and keratophyres in general, we will examine separate spilitic formations and compare them with the formation of the Blyava which has already been studied. Such a comparison of the natural geological groups of rock varieties permits us to elucidate, how important the various deviations from average types are. This is especially important for the spilites, since the variations of their composition are significant.

A. The spilite-keratophyre formation of the Blyava and the volcanic rocks of Karadag mountain: There are still not many chemical analyses of the different rocks of the Blyava

FIGURE 24. The ratio Fe:Mg and the TiO_2 content are dependent on the quantity of femic components (b) in the rocks of spilite-keratophyre formations.

formation here described, but there are enough to construct a petrochemical diagram (fig. 26). All the features of the different rocks that have already been noted are clearly brought out in this diagram. Besides that, the diagram permits us to make the following conclusions about the chemistry of the formation as a whole.

1) This formation appears to be a typical spilite-keratophyre formation. Almost all the points in the diagram are along the line of the average compositions of the spilitic rocks.

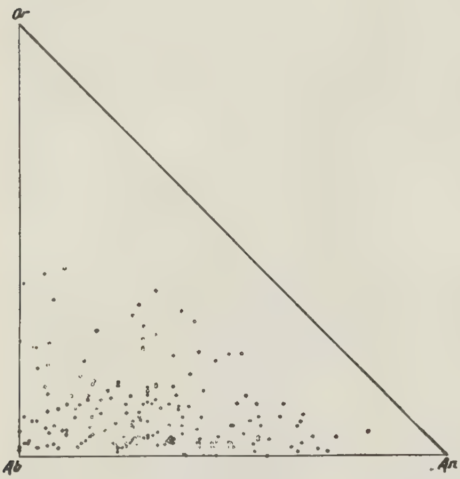

FIGURE 25. Normative composition of feldspars in spilitic rocks.

2) The individual rocks of this formation represent typical varieties of spilitic rocks. The composition of the spilite [2], most typical for this formation is almost identical with the average composition of spilites in general and analogous to the composition of basalt of a normal rock series. The spilitic porphyrite of the formation being described [7] is without doubt analogous to andesites.

3) The deviations from a composition of a typical spilite are noted to be mainly towards calcic-basalt [1, 3].

4) Hornblende porphyrite [8] is distinguished among the keratophyric rocks on account of its higher content of lime. The spilite-keratophyre formation of the Blyava ought to be compared above all with the formation of the Karaday mountain. For this the data of the analyses of the rocks of this formation are marked on the same diagram (fig. 26). In the diagram it can be seen that:

a. In chemical composition the rocks of the Karadag mountain appear to be primarily spilitic porphyrites, though some of them were defined by Levinson-Lessing and Dyakonova-Savelyeva as spilites [6] and keratophyres [13, 15, 16, 17].

b. A few rocks [3, 4, 5] appear to be typical spilites; some correspond to calcic-basalts [1, 2].

c. Silicic members are absent in the spilite formation of the Karadag. The only quartz keratophyres [18] from At-Bashbogaz is described by D. E. Shcherbakov, and is not related directly to the formation of the Karadag mountain.

B. The spilitic rocks of Mugodzhar: The diagram (fig. 27) is constructed according to the data of the chemical analyses of spilitic rocks of Mugodzhar, and it follows from an examination of this diagram that:

1. The majority of the analyses represent rocks of a normal series. Some rocks have a composition of basalts and even of calcic basalts, others correspond to andesitic basalts and andesites.

2. Only the spilite of Kundudza [13] and "the plagioclasic porphyrite" of Auliye [11] appear to be typical spilites.

3. A spherulitic rock of Dzhaman-tau is similar to the spilitic porphyrites of the Blyava.

4. The keratophyres of Dzhaman-tau are similar to the keratophyres of the Blyava.

C. The spilitic formation of England: We may judge the chemistry of the spilites of England from the large number of analyses available, which were all used in the construction of the diagram (fig. 28). A large part of the analyses represents Ordovician rocks and only a few are related to the Precambrian spilites [5, 23, 26, 32] and rocks of a Carboniferous age [19, 21]. It is possible to disregard these few analyses, and compare the spilites of the Blyava with the Ordovician spilites of England.

It follows from the diagram that:

1. The rocks of England here examined consist of a definite spilite-keratophyre formation. The figurative points of the majority of the analyses are arranged along the line of the spilite series, brought out of the whole of the spilitic rocks.

2. The spilites of England differ from typical spilites, and in part from the spilites of the Blyava, in a somewhat higher content of feldspathic lime (c) with a simultaneously high content of alkalis (a).

3. Among these spilites rocks with a composition of calcic basalt are found.

D. The spilites of Karelia: These rocks are

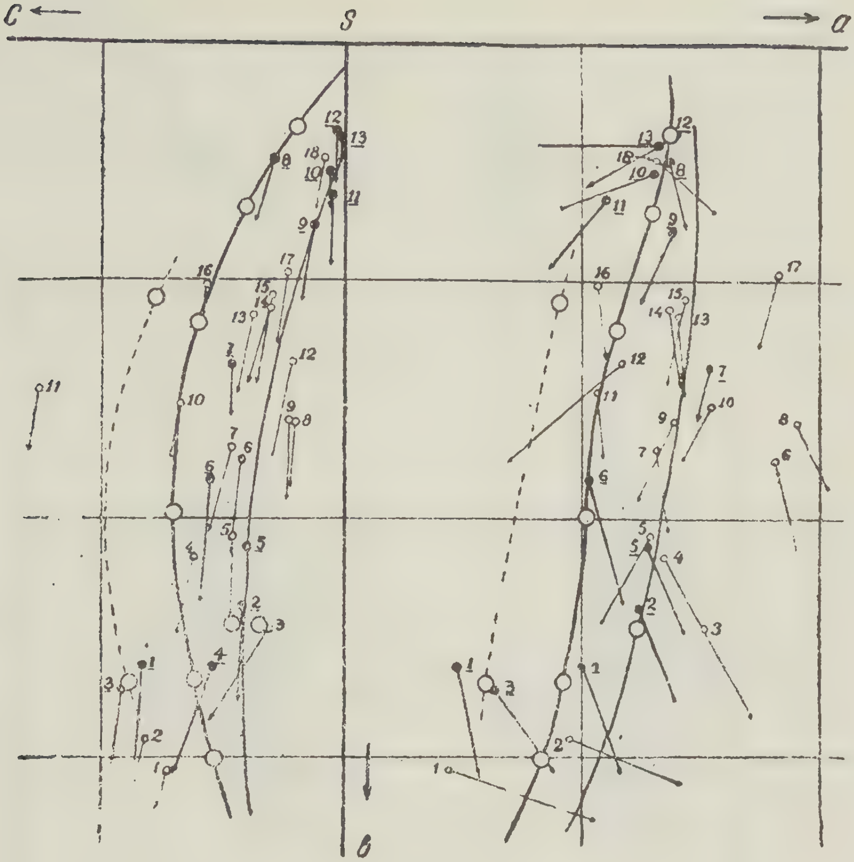

FIGURE 26. The chemical composition of the spilitic rocks of the Blyava and Karadag.

The rocks of the Blyava (points):

1. Diabase with labradorite
2. Spilite
3. A microlitic variety of labradorite
4. Diabase with albite
5. Spilite
6. Variolite
7. Spilitic porphyrite
8. Hornblende porphyrite
9. Keratophyre
10. Quartz-keratophyre
11. Quartz-keratophyre
12. Keratophyre
13. Quartz-keratophyre

The rocks of the Karadag (circles):

1,2,5. Spilite of Karagach [60]
3. The same "mushroom" [60]
4,6. The same "magnetic rock" [60]
7. Keratospilite of Cornelian Bay [60]
8. The same of Gyaur-bak [60]
9. Keratophyre of Monomakh Cap [60]
10. Albitic diabase of Karabai [58]
11. The same of Limen village [58]
12. Keratophyre of Alashga [59]
13. The same "Ivan Razboynik" [60]
14. Grey amygdule [58]
15. Keratophyre of Khobatebe [60]
16. The same of Poychagi cape [60]
17. The same of Karagach [60]
18. Quartz-albitophyre of At-Bashbogaz [59]

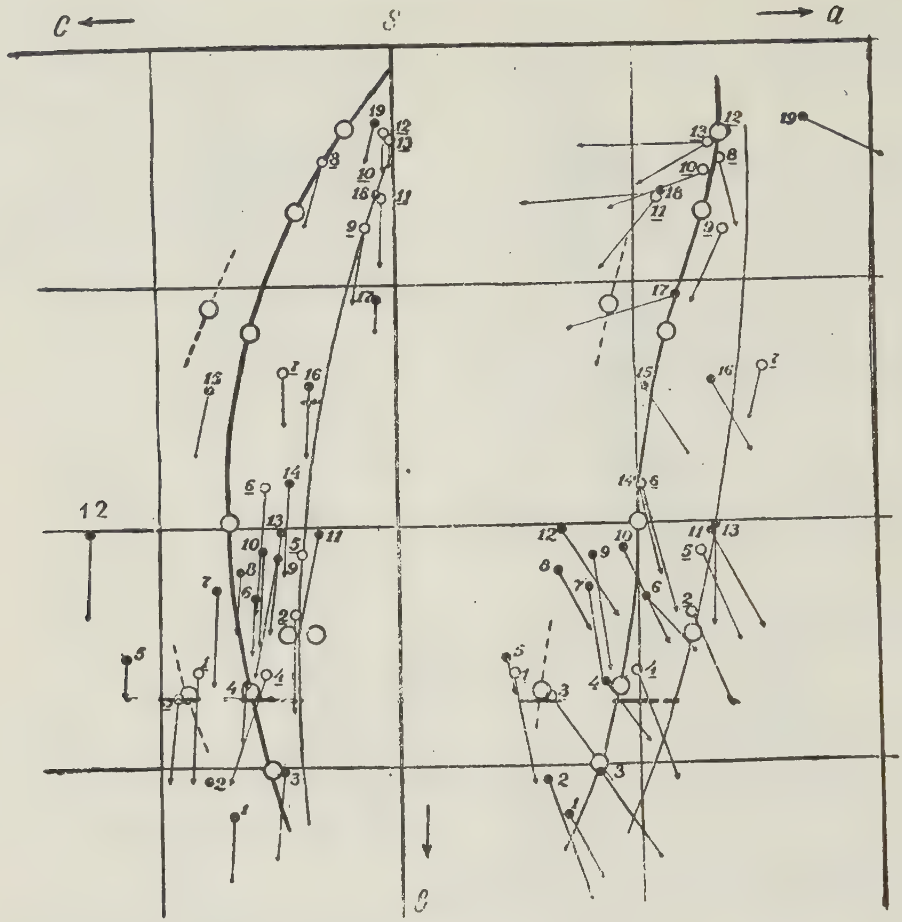

FIGURE 27. The chemical composition of spilitic rocks of Mugodzar. For comparison the analyses of the rocks of the Blyava are marked (small circles, see fig. 26).

1, 4, 5, 6, 7, 8. Glassy spherulitic rocks of Bokhtibai [63]
2. Diabase of Dzhaksy-tau [66]
3. The same of Bokhtibay [67]
12. The same [63]
9. Augito-plagioclasic porphyrite of Ayryuk [67]
10. Porphyrite-Egindy Asha River [67]
11. Plagioclasic porphyrite of Auliye
15. The same of Alabas [68]
13. Spilite of Kundudzy [68]
14. The same of the Ashche-say River
16. Spherulitic rock of Dzhaman-tau [62]
17. Quartz-porphyrite of Dzhaman-tau [66]
18. Quartz-porphyrite of Dzhaman-tau [66]
19. The same of Dzhaksy-tau [66]

also represented by a large number of analyses. From the examination of the diagram (fig. 29), constructed from the data of these analyses, it can be seen [that]:

1. Among the spilitic rocks of Karelia there are encountered both real spilites and also rocks which differ strongly from them.

2. The latter are characterized by a higher content of potash. The vectors conveying the ratio $Na_2O : K_2O$ are significantly more inclined to the left than in spilites.

3. "Potassium diabases" do not generally have a higher content of alkalis (a), as is the case in spilites.

4. The real spilites of Karelia are diverse in chemical composition. Among them there

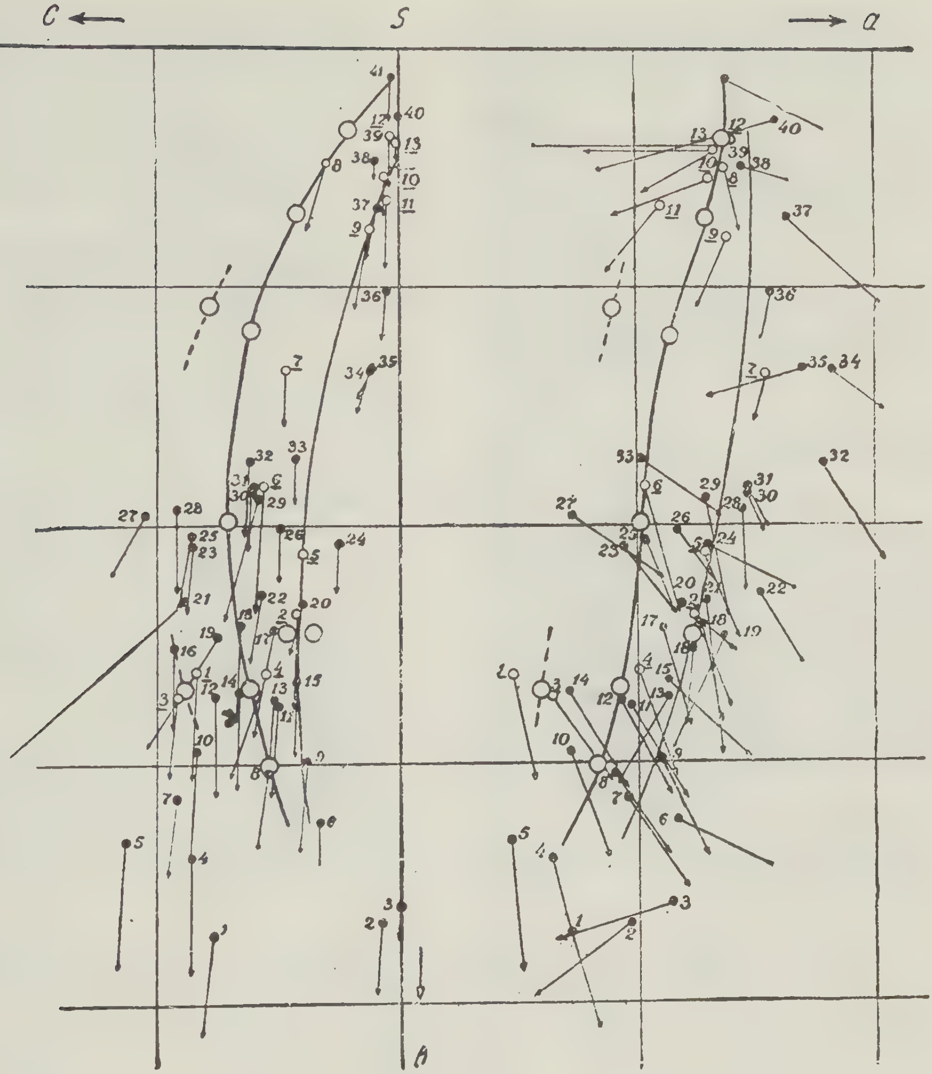

FIGURE 28. The chemical composition of the spilites of England. For comparison analyses of the rocks of the Blyava are cited (small circles, see fig. 26).

The spilites of Cornwall:

1, 17. Pentire Point [17]
4, 22, 27. Camelford [17]
10. Trewint [17]
13. Slade Bridge [17]
16. Port Isaacs [17]
9. Carturther [28]
15. Trevenden [28]
34. Gwavus Quarry [28]
2,3. Trelill Quarry St. Kew [27]
7. Bokelly St. Kew [27]
11. Muelion Island [31] and 30, 31 [17]

Spilites:

6. Newton Abbot, Devon [34]
18. Devonport, Devon [27]
25. Trusham Station, Devon [34]
17. Snowdonia, Wales [45]
24. Tayvallich [28
8, 26. Ardifuar, Scotland [26]
14, 33. Dduallt, Merioneth [44]
5, 12. The island of Anglesey [13]
19. Tidewelt Dall [148]
21. Millers Dall [148]
32. Ayrshire [32]
23. "Pre-spilite" of Ayrshire [43]
20. Mooddzefreet of Skomer [30]
29. Marloezite of Grassholm Island [28]
35. Sodium trachyte of Skomer [30]
36. Keratophyre of Trewenden [28]
37, 38. Quartz-keratophyre of Lizard [31]
39, 40. Sodium felsite of Ireland [38]
41. Sodium rhyolite of Skomer [30]

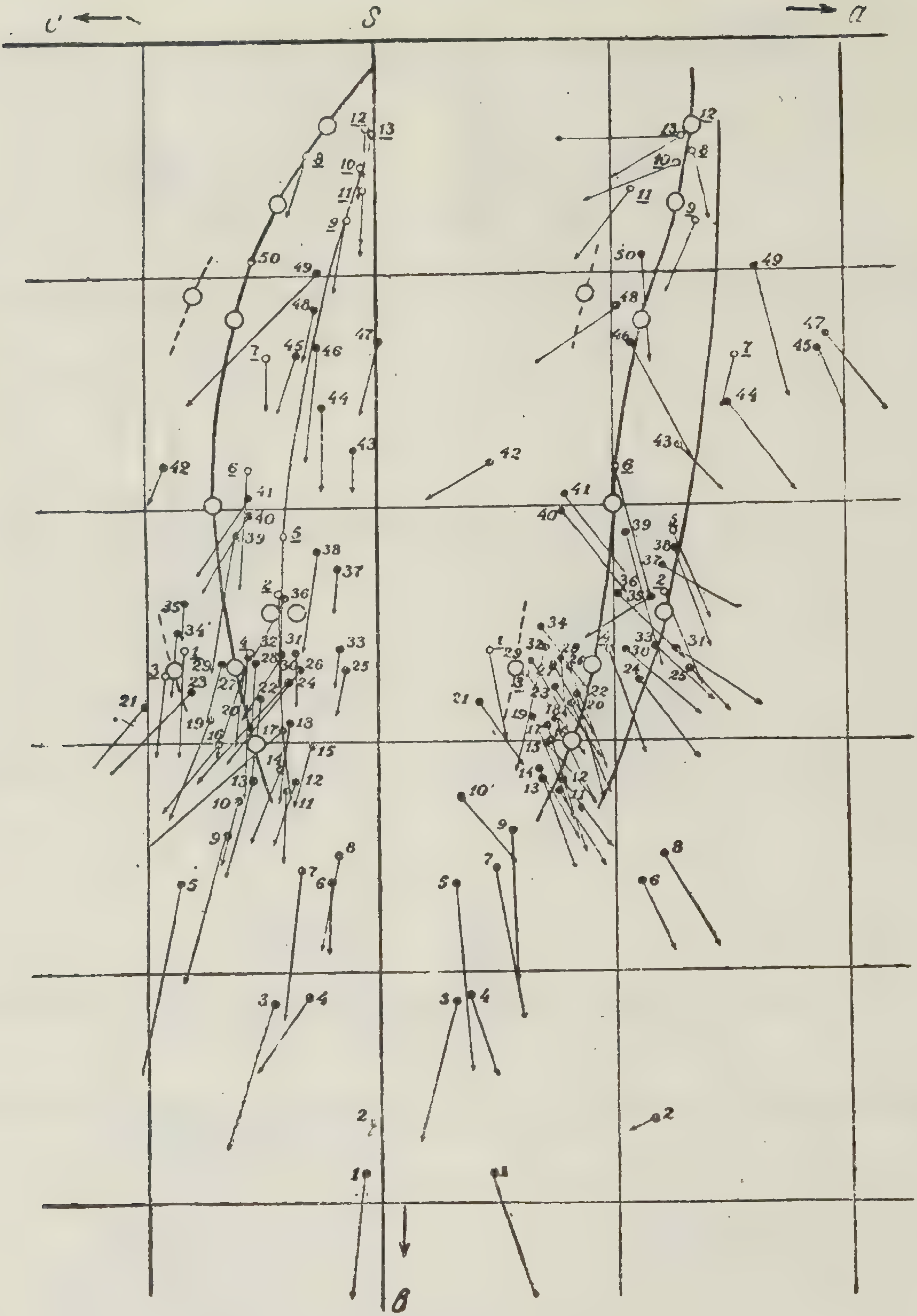

FIGURE 29. The chemical composition of the spilites of Karelia. For comparison the rocks of the Blyava are worked (small circles, see fig. 26).

Diabases:

9. Lake Blizhneye [86]
10. Shunga [86]
11. Rugozero [85]
12. Shcheleyka [86]
13. Lizhma [86]
14. Perguba [86]
15. Onega-Belomorsk watershed [86]
18. Yangozero [36]
19. Mezin-ostrov
27. Nadvoitse [86]
38. Gomselga [86]
42. Masselga [86]

(legend continued on next page)

are those that are close to the spilites of the Blyava [13, 17]. Many correspond in their composition to calci-basalts. The potash diabases of Karelia stand out in the composite petrographic diagram of the spilites (fig. 23). It is possible that they are rocks of another geological formation. It is also possible that the higher content of K_2O is caused by later processes of the metamorphism of these rocks.

E. Other spilite-keratophyre formations: The chemical composition of the rocks composing other formations is not represented by a very large number of analyses.

There are available only a few analyses of the spilites of Australia, Norway, Oregon, and odd analyses of the spilitic rocks of other places.

All these rocks have been entered into a composite diagram of spilites (fig. 23), but it is pointless to examine the remaining formations with it, since three to four analyses cannot represent a complete formation.

Chapter 10. Albitization and the Genesis of Spilitic Rock Types

On the formation of albite from Magma

The question of whether albite appears in spilitic rocks as a mineral crystallized directly from the melt, or whether it formed as a result of metasomatic substitution of another feldspar, was in the beginning considered important for the solution of the spilite problem. This question is now settled. The metasomatic origin of albite is indicated by the constant association of spilitic rocks with normal calc-alkaline rocks, by the existence of a typical alkalic rock with albite together with a rock of basaltic composition in one flow or even in one piece of rock, and, most important, by the existence of remnants of basic plagioclase or potash feldspar inside the albite of the spilites or keratophyres.

Albitization undoubtedly took place in all types of spilitic rocks and there may be doubt only as to whether all of the albite was formed as a result of it.

In examining this question one usually makes a distinction between the formation of albite in spilites and in keratophyres.

There have not been very many supporters of a magmatic origin of albite in basic rocks. At first when strong alteration was considered characteristic for spilites, the albitization or "deanorthitization" of plagioclase was considered a natural consequence of the processes of general alteration of the rock. But when Benson [50], and after him Sundius [94], established the presence of apparently completely fresh albite with unaltered pyroxene, there arose suggestions about the formation of albite from magma.

The first to oppose these propositions of Benson was Eskola [81]. Pointing out that in spilites plagioclase and proxene crystallized

LEGEND FOR FIGURE 29 CONCLUDED.

Spilites:

2. Povenchanka river [86]
6. Messelga [86]
20. Padany [81]
22. Perguba [86]
25. Kulmuksa [81]
33. Konchozero [81]
34. Segozero [82]
37. Petrozavodsk from a "solomon breccia"
43. Yangozero [81]

Variolites:

26,39,45,47,48. Suisari [86]
35. Westshore of Lake Onega [86]
26,30,36,40,41. Yalguba [76]

Porphyrites:

1. Linguba [86]
8. Petrozavodsk [86]
44. Chernaya [Black] Vaaraka [85]

Amygdales:

17. Vormnoborsky mountain ridge [86]
28. Perguba [86]
32,46. Yalguba [76]
4, 7. Augite porphyrite of Suisar [86]
23. The same of Yalguba [76]
3. Uralitic porphyrite of Yunk [81]
5. Proterobaz of Ersha village [76]
29. Diabase-porphyrite of Gus-ozero [86]
Diabase felsite of Yalguba [76]
16,21. Aphanite of Sandal-ozero [86]
48. Quartz-keratophyres of Kosozero [85]
50. Porphyrite-like rock [86]

simultaneously, as can be seen from the fabric of the rock, Eskola maintained that this could not have taken place if the plagioclase had been albite. In contending this, he cited the experimental studies of N. L. Bowen [157] on the albite-diopside system, which demonstrated that simultaneous crystallization of these minerals is possible only if there is 97 percent of albite. This did not seem to convince Sundius [97] who rightly noted that magma is not an albite-diopside system, and that the presence of iron ought to remove the eutectic from the albite. Sundius could not have known how the composition of the eutectic changes, since this had been ascertained only a few years later. New experiments by Bowen and D. Schairer showed that the displacement of eutectic was negligible. In an albite-fayalite system simultaneous crystallization takes place if there is 85 percent of albite.

Thus the objections of Sundius lost strength, but this does not mean that his experimental studies on "dry" systems proved that a formation of albite from magma rich in volatiles was impossible. We do not know what the composition of those volatiles was, and how they influenced the composition of the minerals formed from the magma. Therefore to speak about the impossibility or the possibility of the formation of albite from magma is meaningless. Many petrologists, in particular V. N. Lodochnikof [159], contend that the formation of pure albite from magma containing some amount of CaO and Al_2O_3 would contradict the "generally accepted laws of distribution of oxides in a homogeneous liquid phase" [157].

The formation of albite from magma with a composition closely comparable to that of keratophyres, i. e. hardly containing any CaO, is considered more probable. However, even here we have no evidence that this has ever taken place anywhere. Albitization in keratophyres doubtlessly took place on no less a scale. Not only plagioclase, but also potassium feldspar was replaced by albite.

The time of albitization

When explaining the origin of spilitic rocks solely by albitization, one has first of all to find out whether the latter proves to be an autometamorphic process, or has been caused by external factors not at all connected with the formation of primary rocks. In the last century Termier [152] associated albitization or "de-anorthitization" of basic plagioclase with the processes of weathering. In 1909 E. Bailey and G. Grabham [154] were the first to express the idea of a late-magmatic origin of albite. Dewey and Flett [28] agreed with them, and since then most petrographers have held to that opinion. Some authors could not conceive of the broad development of the autometamorphic processes in extrusive rocks, and therefore explained albitization by different causes: in 1915 Sundius [92] by regional metamorphism, in 1935 Gilluly [110] by evidence for postmagmatic solutions from the intrusion of sodic granites. These hypotheses do not have sufficient foundation. Not all spilites underwent regional metamorphism, and intrusions were not near many of them at the time when the same process of albitization became apparent everywhere. Therefore it is simpler to conceive of a connection between albitization and the formation of primary rock types, the more so as this process was one and the same in all spilitic formations. Non-albitized rocks are found principally in clastic volcanic rocks on the Blyava and in some regions of England [47]. Such rocks form the central parts of the flows on the Blyava, or are found only in the larger flows. This points to some dependence of the processes of albitization on volcanic eruptions. Therefore it is proved to a certain degree that albitization appeared to be an autometamorphic process which took place after the rock had hardened, but before it cooled completely.

The conditions of cooling of lavas under water

It is beyond doubt that the lava flows of spilitic composition are under-water extrusions. In most cases this is directly indicated by the interbedding of spilites with radiolarian jaspers and other ocean sediments. The broad development of typical pillow lavas, unknown in rocks formed on the surface of the earth, may also serve to indicate the under-water nature of the extrusions.

The assertions of Backlund [123], that some spilites have apparently developed in surface conditions, are not substantiated. Among present day volcanic rocks doubtlessly formed under terrestial conditions, spilites are unknown. It is difficult to imagine that they would not develop at the present time too; apparently they are only hidden under water.

Conditions of crystallization and underwater cooling of lava are different from those on the surface of the earth. In under-water conditions lavas do not undergo the process of oxidation. This can be explained not only because the quantity of free oxygen in sea water is less than in air, but also because several minerals, like hematite and iddingsite, though very widespread in basalts, are unknown in spilites.

Insofar as exothermal reactions of oxidation were absent, the temperatures of lavas under water were lower than on the surface. The immediate ranges of temperature of basalt lava in the zone of oxidation are 1000 to 1185°, but outside that region they are only 750 to 900° [160,]. The hydrostatic pressure in underwater conditions reached several tens and

perhaps even several hundred atmospheres, depending on the depth. For every 10 m of depth in water the pressure grows approximately one atmosphere. In the crust of the earth pressure increases with depth 2.5 times as quickly.

The cooling of lavas in submarine conditions took place at a considerably faster rate than on the surface of the earth, since water is a far better conductor of heat than air. From the practice of tempering steel it is known that cooling is ten times quicker in water than in air.

Apparently the formation of "glassy and variolitic" rocks of a basaltic composition is possible only in underwater conditions.

Volatile components in lavas extruded under water are retained in greater quantity than in lavas extruded on the surface of the earth. Many authors, Bailey and Grabham [154], Dewey and Flett [28], Wells [41], and others, explained this by a quick formation of an impermeable glassy shell. However, the existence of vesicular zones in the periphery of the pillows of lavas shows that the boiling up, i.e. a partial escape of gas from the lavas, took place and that there is no foundation for speaking of the impermeability of a glassy shell. The small quantity of volatiles effused from the lavas was determined by the higher outside pressure and also by the absence of a way out for the gas in the surroundings.

The source of sodium and the features of albitization in spilites

The albitization in all the spilitic rocks appears to be a chemical reaction of the exchange between crystallized calc-sodium or potassium feldspar and the liquid or gaseous solutions containing Na_2O, and capable of dissolving CaO and K_2O.

The physical state of these solutions cannot be determined. However, at the present time most petrologists and mineralogists insist on the liquid state of the post-magmatic solutions. D. S. Korzhinsky [160], on the basis of the analyses of metamorphic reactions from the point of view of physical chemistry maintains that all these reactions take place in the presence of aqueous liquid solutions. As is known the solubility of gases is slight, but in the super critical state during albitization in spilites the solutions were apparently not present. The experimental studies of Eskola and his coworkers [156] showed that the albitization of basic plagioclase in the presence of a surplus of CO_2 and H_2O takes place best of all at 310 to 330° C, i.e. lower than the critical temperature of water (374° C).

The exceptional degrees of albitization in spilitic rocks indicates that the quantity of Na_2O which came out of the solution is very large. As to whether this quantity was contained the whole time in the solution saturating the rock, or whether Na_2O was continuously added from outside there is no consensus.

Bailey and Grabham [154], Dewey and Flett [28], Wells [41], and many others have regarded the post-magmatic solutions as residual from the same melt as the consolidated rock. In their opinions albitization took place under conditions of a closed system under some kind of "rock-stewing in a concentrated solution of sodium carbonate".

Beskov [101] considered albitization from quite a different point of view. In his opinion this process took place under conditions of an open system. The quantity of sodium in the solution did not diminish as a result of the reaction, since an uninterrupted supply was available from sea-water.

The sealing-off of lavas that are cooled by sea-water is not brought about as a result of the "speedy formation of a glassy cover", as assumed by Dewey and Flett [28]. If albitization had taken place in it, this must also have been saturated by postmagmatic solutions. The sealing off of lavas can only be the result of the formation around them of a gaseous shell preventing diffusions of ions. Such a crust is only possible through the contact of lavas heated to 310° with pure water under a pressure of less than 97.4 atmospheres, i.e. at a depth of less than 970 m. When there is contact of lavas with sea-water containing different salts in solution, then, according to G. Beskow, even at lesser depths (up to 100 m) the formation of a gaseous phase is impossible. The evaporation of the water doubtlessly gives rise here to an increase in the concentration of salts, which will lead in return to the condensation of steam.

Thus Beskow's idea of the immediate contact of the cooling rock with the sea water and the possibilities of an exchange of substances between them is better founded than the idea of a closed system. However, it is hard to conceive that only sea-water should have been the source of sodium in postmagmatic solutions. Underwater hot springs, which correspond to fumaroles and solfataras on the surface of the earth, have continually emanated a considerable quantity of sodium from a volcanic hearth, and its concentration around the extruded lavas was apparently more than average.

Because of the great mobility of the sodium ions [161] albitization did not change their concentration in the solutions saturating the rock. Sodium was everywhere in abundance. The reaction continued almost always to the end, i.e. until the substitution of plagioclase or potassium feldspar was complete. The reaction

did not depend on the composition of the plagioclase. Labradorite is replaced by albite, as well as andesine is in more silicic rocks. It is true that "oligoclase" and even "andesine" are sometimes indicated in earlier literature as being contained in spilites, but this apparently is the result of an inaccuracy of determination. As a rule albite in all spilitic rocks contains hardly any anorthite.

The presence of albite in amygdules and veinlets in rocks with already albitized plagioclase indicates an abundance of sodium even after albitization has ended.

Besides sodium, carbon dioxide and water were fully volatile components [161]. Bailey and Grabham [154] have pointed out that albitization takes place when there is plently of carbon dioxide. Thanks to the experiments of Eskola [156] this has nearly been proved.

Calcium and potassium freed during the reaction must also be considered volatile components. As a rule they came out of the rock, though in some regions calcium minerals were formed (chiefly calcite and prehnite). The formation of these minerals out of the solutions evidently took place under different conditions.

Silica, indispensable for the replacement of anorthite by albite, was also found in the solution. Whether it was found in the form of soluble silicates of sodium or in some other form is not known. It is obvious only that under conditions of an open system the volatility of silica was considerably less than that of sodium [161]. Therefore it could hardly have been brought from the outside together with the sodium.

Eskola's experiments [156] have shown that the decomposition by carbonic acid of orthosilicates of iron magnesium takes place simultaneously with albitization. Thus silica is set free and can enter the formation of albite. In the rock types that change into spilites the quantity of olivine was slight, and it could not have been the chief source of silica, but the experiments of Eskola explain why this mineral is not to be found in spilites.

The source of silica is apparently the glass. Even in the most recent spilites of Karadag the glass is completely replaced by chlorite. In the Mugodzhars, it is true, glassy rock types [69] are well known, but here they did not undergo any albitization. Nowhere has glass in rock types been shown with albite, and it is hardly possible [that glass can remain] here.

The correlation of SiO_2, Al_2O_3 and other oxides in glass is such that during crystallization pyroxene and plagioclase should have been formed. During the decomposition of glass into delessite the alumina of plagioclase united with the oxides forming part of the composition of pyroxene, but the lime, sodium, and silica of plagioclase entered into solution. Considering the volatility of these components the concentration of the solution of CaO and Na_2O was not of much significance, but albitization depended to a certain degree on the concentration of the silica. From this too perhaps can be explained the fact that non-albitized rocks are as a rule well crystallized, i.e. they scarcely contain any glass.

The decomposition of glass simultaneously with albitization not only enriched the solutions with silica, but also furthered the saturation of the rocks with the solution, which made the exchange of substances much easier. Perhaps therefore a freer growth of crystals took place, and zoned crystals are absent.

On spilitic magma

The idea of albitization in spilitic rock types as being reactions between the rock and the residual solutions under conditions of a closed system required acceptance of the proposition that there was a very large quantity of sodium and silica in the lavas. Yet even the quantity which is needed for a reaction, amounts to 10 to 15 percent of the whole rock mass. But the total quantity of the constituent parts of the residual solution will be considerably larger.

And so, in addition, Dewey and Flett [28] assumed the existence of a special spilitic magma differing from the usual basaltic magma by a larger content of water and other volatile components.

This assumption was accepted by everyone; many admitted that even basaltic magma contained a sufficient quantity of volatiles, and that only their rapid loss did not allow them to be converted to it [spilite]. The one assumption as well as the other is founded more on our ignorance of the structure of magma than on any factual data.

Under conditions of an open system, which, as mentioned, is more likely to occur, it is not necessary to assume a magma with a higher sodium content [than normal].

The lavas apparently differed little from those which under ordinary conditions yield rocks of a normal calcic series.

Chapter 11. The characteristics of spilite-keratophyre formations

A petrographic study of volcanic rocks of the western slope of the south Ural Mountains and their comparison with analogous rock types from other districts enables us to form the

following conclusions, which have perhaps some general significance for petrology:

1. Spilite-keratophyre formations appear to be complexes of extrusive rocks differing in silica content, but formed in the course of a single prolonged volcanic cycle under special geological conditions.

2. All the features of the mineralogical composition of the rocks of these formations, that distinguish them from rocks of a normal calc-alkalic series, are caused by the geological conditions of the [process of] formation, and not by the composition of the lavas.

3. The formation of the rocks took place under water. Underwater extrusions of lavas were accompanied by intense activity of underwater "fumaroles" and hot springs.

4. As a rule all types of spilite-keratophyre formations were autometamorphosed and formed as a result of albitization under the action of hydrothermal [deuteric] solutions. These solutions saturated the rocks and continually took some quantity of sodium carbonate from the hot underwater springs and the sea water.

5. The rocks, from which the spilites and keratophyres were formed, can be recognized from those portions which by chance have not undergone albitization. The most recent of all the spilite-keratophyre formations appear to be normal calc-alkalic rocks.

6. The continuous transitions of albitized into unalbitized rocks, and the co-existence of these and other rocks in one flow impedes their separation. There fore "spilite" and "keratophyre" become collective petrologic concepts, the same as "trap", "plateau-basalt", etc.

7. The geological conditions of the [process of] formation distinguish spilite-keratophyre formations from andesitic, or rather rhyolitic-basaltic formations of contemporary geosynclinal regions and trap formations of continental platforms.

8. Spilite-keratophyre formations do not have analogies among intrusive rock formations. Some spatial relation of spilites is outlined with intrusions of ultra basic and basic rocks differing significantly in age.

9. The difference between separate spilite-keratophyre formations are caused mainly by their subsequent metamorphism, which is not connected with the [original process of] formation of spilitic rocks.

10. The study of contemporary underwater extrusions, more than anything else, will help us form a final answer to the spilite problem.

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SPORE-POLLEN COMPLEXES OF UPPER DEVONIAN OF THE RUSSIAN PLATFORM[1]

by

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- translated by Ivan Madirazza -

PREFACE

This translation is the first of several that have been made by geology students working part-time in conjuction with the U. S. Geological Survey program of plant microfossil investigations. The manuscript of this translation was prepared by Ivan Madirazza, under the supervision and with the assistance of the writer, in 1957. Additional corrections have been made with respect to word order, modes of expression, spore terminology, and stratigraphic usage (which is especially difficult to interpret), so that I believe the essential Russian meaning has been successfully translated into English with few points of uncertainty. A reader, however, should regard this material as an aid to interpretation of the original, and the Russian text should be consulted for critical reference or quotation.

The portion of Naumova's report that is presented here omits most illustrations, and diagrams, and all systematic descriptions. It also omits chapters discussing spore assemblages, ecologic interpretation, stratigraphic principles, and stratigraphic distribution (p. 132-152). However, American students will soon have ready access to the new specific descriptions (in Russian), with accompanying illustrations, in Volumes 11 and 12 of the "Catalog of Fossil Spores and Pollen" issued through the Geology Department, College of Mineral Industries, at The Pennsylvania State University, University Park, Pa. A complete French translation is available through the Service D' Information Géologique (S. I. G.) du Bureau de Recherches Géologiques et Minières (B. R. G. M.), 74, rue de la Fédération, Paris (XV^{e}), France. [No. 1324, Naumova, S. N., Complexes sporo-polliniques du Dévonien supérieur de la platforme russe, et leur valeur stratigraphique. Texte (128 p.) 20 NF (2000 F); illustration (19 pl.) 10 NF (1000 F)]. I am uncertain whether the fold-out spore distribution diagrams (plates 20-22), and the accompanying tabular guide to spore-pollen complexes, are included in the French translation. All illustrative material was omitted from the set of contoura negatives of the rough, but complete, typescript version of this translation which was circulated in 1959 to interested individuals, on a copy-it-yourself basis, through the cooperation of Dr. R. M. Kosanke of the Illinois State Geological Survey. It should be emphasized that the original Russian edition is of value, even to those who do not read Russian, for the sake of its illustrations. --James M. Schopf.

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FOREWORD

The necessity for stratigraphic separation and dating of continental, lagoonal, and marine terrigenous strata, which are usually characterized by a meager fauna and by a relatively rapid change in detail from section to section, is becoming more acute with transition to large-scale geological survey work. Utilization of ostracods and other microfaunal groups usually fails to achieve stratigraphic separation because of environmental change in the deposits. Mineralogical analytic data give good results for the comparison of different sections over short distances, but prove insufficient for more distant comparisons.

Fragments consisting of spores and pollen (that are often present in large numbers in such deposits) assume a completely unique significance but up to now have not attracted the necessary attention. These fragments will have special importance in supplementing other paleontological, especially paleobotanical, materials for the separation of Paleozoic terrigenous deposits of the Russian platform and Siberia. The lack of criteria for separation of these strata is especially acute at the present time in view of widespread prospecting at depth for Devonian oil and other useful mineral resources of the Russian platform.

It was in conjuction with these problems that the study of spores and pollen from Upper Devonian deposits was organized at the Spore-pollen Laboratory, Section of Stratigraphy of the Institute of Geological Sciences, Academy of Sciences, U. S. S. R., as one means of determining the practical applicability of spore-pollen analysis in deciphering the stratigraphy

[1] Translated from Sporovo-pyltsevyye kompleksy verkhnego devona russkoy platformy i ikh znacheniye dlya stratigrafii: Trudy Instituta Geologicheskikh Nauk, Akademiya Nauk SSSR, Issue 143, Geologicheskaya Seriya, no. 60, 1953. Translation supervised and edited by James M. Schopf, U.S. Geological Survey, Columbus, Ohio. Published with permission of the Director, U.S. Geological Survey.

of older series. Complementary studies were undertaken by normal paleontological methods to provide a verification of the results. The present paper summarizes results of these investigations.

In addition to the author, N. G. Pykhova participated in the work as Junior Scientific Aide; V. N. Knorozova, Technical Artist, calculated the quantitative occurrences of spores and pollen; T. V. Pogozheva, V. K. Bolshakova, and A. I. Pulik, laboratory assistants, made the macerations of the rock.

Drawings of spores and pollen under the microscope were prepared with the aid of drawing apparatus, at a magnification of 400 times, by V. N. Knorozova, artist, and N. O. Rybakova, botanist.

More than 700 samples from the Devonian of the Russian platform served as materials for investigation.

I am deeply grateful to V. V. Menner and A. N. Krishtofovich for valuable suggestions and criticism of the results that have been obtained.

Spores and pollen were isolated from the rock by methods normally used by us for ancient deposits. All rock specimens analyzed were crushed to pieces smaller than 0. 5 mm. After this, carbonates were removed by use of HCl; subsequently the samples were oxidized with concentrated nitric acid. After a triple decantation with water, the sediment was flooded with 10 percent KOH, boiled for 6 minutes, and the sediment again was decanted with water.

The separation of the spores and pollen from the residue was performed directly, with the aid of the electric centrifuge, in Thoulet's solution of 2. 25 specific gravity. The residue with the spores and pollen was washed in water and studied under the microscope with transmitted light.

The contents of the residues and preservation of the spores and pollen is closely related to the types of sediment. Accordingly, one must consider coastal-marine environments, lakes, and marshes, that is to say, the deposits formed in stagnant and sluggish water, as most favorable for finding spores and pollen.

The following belong to these environments: black, gray-black, gray-brown, and cinnamon-colored rocks; coal, carbonaceous shale, clay shale, siltstone, marl, fine-grained sandstone, and littoral gray limestone.

Spores are rare or absent in the following environments: deep water-marine limestones, sediments deposited from swiftly flowing rivers, erosion crusts, and chemical sediments having white, red, dark-brown, violet, and light-yellow color, which include white limestone, variegated rocks, clays, clay shales, siltstones, gravel, and kaolinitic clay.

Most of the samples investigated contained a significant quantity of well-preserved spores and pollen indicative of favorable conditions for fossilization. Of the 700 samples, represented for the most part by shale, siltstone, clay, and marl, 400 samples proved to have a sufficient quantity of spores and pollen for quantitative as well as qualitative analyses (200 examples of spores and pollen from each sample). Drawings were made of all the species encountered in each sample.

All morphologically described spores and pollen are pictured in Plates 1-19. [Not included in translation. J. M. S.]

Only the leading or predominant (more than 3 percent) types of spores and pollen in sections, layers, and suites of Devonian deposits are shown in appended diagrams XX-XXI. [Not included in translation. J. M. S.].

INTRODUCTION

The first investigations of spores of the Devonian were made at the end of the 19th and the beginning of the 20th century, in connection with the study of the reproductive organs of the most ancient land plants.

The process of formation and development of spores was studied, at the end of the last century, in the sporangia of Devonian plants provisionally named by J. Clarke Sporangites huronensis Daws. (Clarke, 1885).

Later, A. G. Nathorst described and illustrated spores of Archaeopteris, a fern widely distributed in the Upper Devonian (Nathorst, 1902). D. White and T. Stadnichenko (1923) described tetrads of cutinous spores from the spore-bearing parts of Foerstia ohioensis White from the Upper Devonian black shale of the State of Ohio in America. R. Kidston and W. Lang also described tetrads of cutinous spores from fertile fragments of Sporocarpon furcatum Daws. in discussing the problem of the systematic position of these plant fragments (Kidston and Lang, 1924-1925). In addition, W. Lang discovered eight spores differing in size and form in the Middle Devonian deposits of Scotland, which were not assigned by the author to any plant (Lang, 1925).

P. A. Nikitin (1930) described the megaspore Kryshtofovichia africani Nik. from the Voronezh Devonian.

Finally, spores of the Devonian plants Svalbardia and Enigmophyton were described

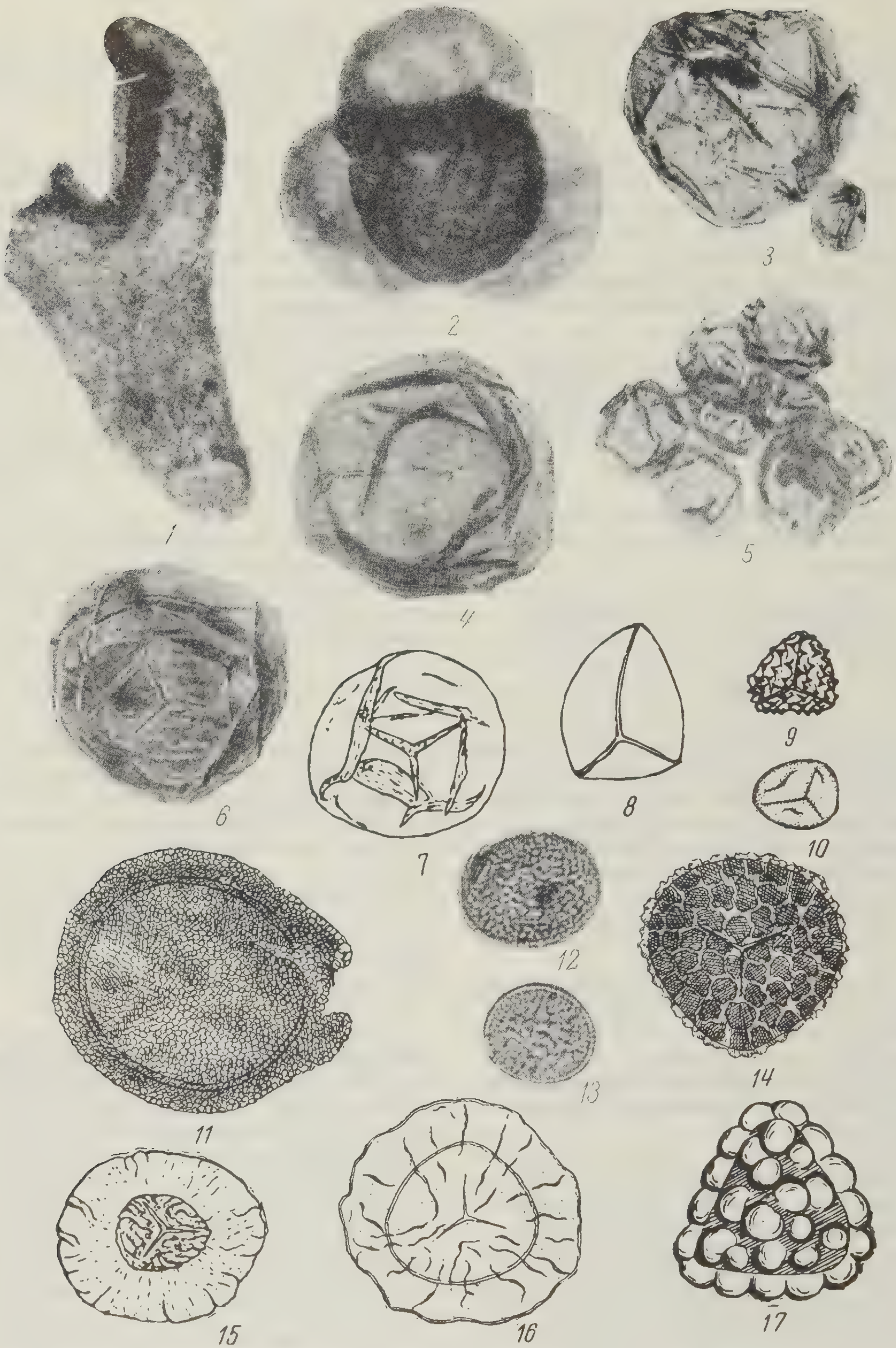

FIG. 1. Fossil and contemporary spores and pollen: 1-Dichotomously branched shoot, Sporocarpon furcatum U.Daw. Spore tetrads along the edge of the indentation; U.Dev. x 50. 2-Tetrad of cutinized spores, sporangium of Sporocarpon furcatum U.Daw.; U.Dev. x 150. 3-Macrospores and microspores of Macrostachys infundibuliformis (Br.), U.Carb. x 120. 4-Macrospore of Paracalamostachys striata Weiss; U.Carb. x 170. 5-Microspores of P. Striata Weiss; U.Carb. x 170. 6-Spore of Macrostachys carinata Andr.; U.Carb. x 360. 7,8-Spores of Calamostachys sp.; U.Carb. x 380. 9-Spore of Sphenophyllostachys cf majus Bronn.; U.Carb. x 380. 10-Spores of contemporary Trichomanes scandens. x 500. 11-Macrospore of contemporary Salvinia natans L. x 200. 12,13-Pollen of contemporary Potamogeton natans L. x 400. 14-Spore of Dicksonia arborescens L. Herit. x 600. 15-Spore of Sphenopteris sp.; U.Carb. x 380. 16-Spore of Selaginella rupestris, x 500. 17-Spores of Alsophia chimborazensis, x 500. (1-2 after V. Deson; 3-6, V.Hartung; 7-9,15, L.Mur; 10,12,13 S.N.Naumova; 11, M.A.Sedova; 16,17, E.Knox).

by A. Høeg (1942) from deposits from islands of Spitzbergen.

Thus the early works dealt for the most part with the spore remains, permitting the explanation of the systematic relationship of various extinct groups of plants, but hardly touching the problem of the stratigraphic meaning of the spores.

The spores were investigated under low magnification and, because of this, morphological descriptions cited in these works were general and insufficiently accurate; the work was instrumental in relating spores to definite plants by their discovery directly within sporangia.

The problem of the stratigraphic significance of spores for the Devonian was posed for the first time in U. S. S. R. coal geology in the early thirties when M. V. Elovskaya (1936) studied and described seven forms of spores from coals of the Middle Devonian from the vicinity of Barzass and Kuzbass, and A. A. Lyuber did the same for eleven spore forms from Middle Devonian coals of the Volongi River (Lyuber and Valts, 1941).

In the same year S. N. Naumova described 65 forms of spores and pollen from carbonaceous deposits of the Frasnian stage in the Voronezh region (Dubyansky, 1948).

Finally, W. Thomson (1940) described 20 forms of spores from carbonaceous shales of the Middle Devonian in Estonia. The works mentioned above confirmed the common preservation of spores in Devonian coals, and indicated a necessity for their detailed stratigraphic study. Thus it became possible in 1945 to formulate the problem of utilizing spores for general differentiation of Devonian deposits, and led to an attempt to separate the spores, not only from the organic sediments, but also from terrigenous sediments, including some which are marine.

In the first stages of investigation a greater quantity of spores and pollen was discovered in various sediments of the Frasnian stage of the Devonian. Their preeminent stratigraphic meaning was established immediately. Thus the prospects were enlarged for use of the spore-pollen method in dating terrigenous strata which have been so difficult to differentiate.

However, up to the present time the Devonian spores have been only slightly studied. Not more than 100 forms in all, principally from the Middle Devonian and Lower Frasnian stage, are described in the literature. At the same time, the practical significance of spores requires that they be studied much more thoroughly. The present work is intended to cast light on the composition of the spore-pollen complex of the Frasnian stage, and is only partly concerned with the adjacent deposits.

Future development of the work on spores of the Devonian will undoubtedly extend our knowledge of one of the most ancient floras of the earth and improve the accuracy of results, offered below, which represent only a first approach to the problem.

CHAPTER I

Discoveries of Devonian land floras, especially those of the ancient type, are comparatively rare (Krishtofovich, 1927).

The Lower Devonian flora has long been considered the first dry-land flora known to paleobotanists, but recent discoveries in Sweden, Australia, Scotland, and Norway show that rather highly developed forms, completely organized rhyneans and psilophytes, already existed in the Silurian. However, plant remains from the Silurian [i. e., Siluro-Ordovician. J. M. S.], are exceedingly sparse (Krishtofovich, 1941), and particularly so from the Cambrian.

Recent discoveries of a large number of spore forms in the Lower Silurian [=Ordovician J.M.S.] and Cambrian, indicate already a rather significant development of higher spore plants in these remote times (Naumova, 1949).

As shown by A. N. Krishtofovich, the emergence of plants on dry land along the shores of basins was accompanied by the rise of a new systematic type of plant known as the Psilophyta.

Plants united under the name Psilophyta are less organized [more primitive - J. M. S.] than pteridophytes and have no leaves at all or bear only small appendages (Seward, 1936).

The psilophytes are represented by small or medium-sized plants, for the most part dichotomously branched, sometimes having the appearance of algae or club mosses, devoid of root systems, bare or with bristly appendages, with sporangia most frequently located terminally on the ends of shoots, occasionally in the axils of leaves. Psilophytes are characterized anatomically by the presence of a woody central column of spiral tracheids, invested by phloem (Krishtofovich, 1927a, 1941).

The psilophytes, being a transitional group between the algae and the pteridophytes, include various prototypes of the latter class. As a consequence, the more highly organized psilophyte representatives form a direct transition to various pteridophytes.

The psilophytes reached their greatest development in the Middle Devonian during which <u>Rhynia</u>, <u>Psilophyton</u>, <u>Hornea</u>, <u>Asteroxylon</u>,

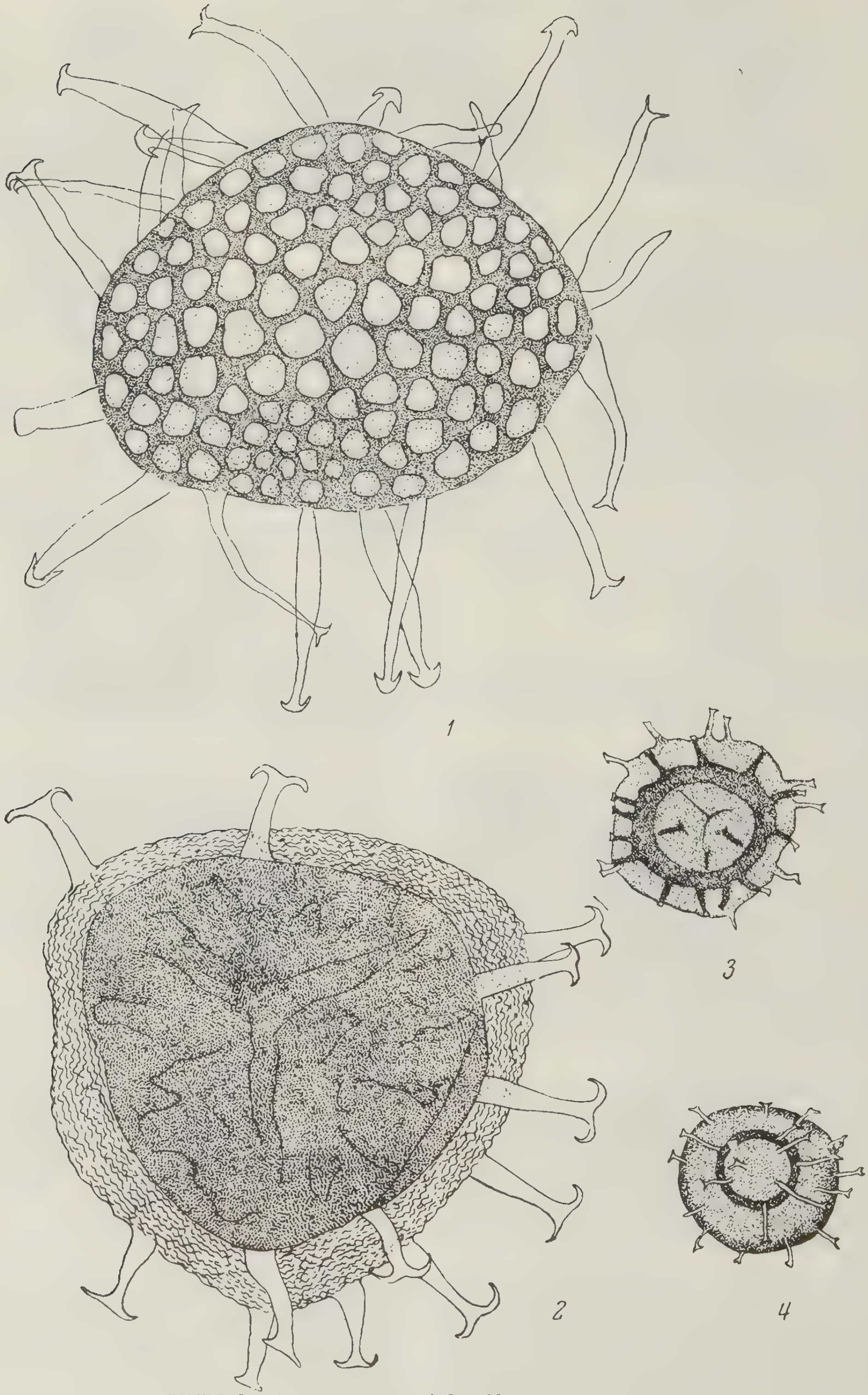

FIGURE 2. Contemporary and fossil spores
1 - Spore of the contemporary Hydropterineae Azolla, x 400 (after S.N. Naumova).
2,3 - Devonian spore of the type Azolla, x 400 (after S.N. Naumova).
4 - Spores of the type Azolla from the lower Silurian of the Baltic Sea region, x 400 (after S.N. Naumova).

Zosterophyllum, and others, appear to have been widespread. Primitive ferns, which appear with them, or somewhat later, such as Leptophleum, Protolepidodendron, Protoarticulateae, and Calamophytales, are often encountered (Seward, 1936; Krishtofovich, 1941).

The flora of the Upper Devonian was represented by more highly organized plants. The highest development included Filicales, Lycopodiales, and Pteridospermae. Forms of the Gymnospermae began to appear after the Middle Devonian. Protective adaptations of the seed buds on some plants indicate the existence of dry periods in the Upper Devonian (Krishtofovich, 1941).

In the Devonian, as is known, coal beds of commercial importance made their first appearance. Moreover, all known places of occurrence of these Devonian deposits are on the Russian, Siberian, and Canadian platforms.

Indications suggesting appearance of coal are observed in the Middle Devonian (Eifelian in Germany; Seward, 1936), although the first signs of humic coal already appear in the Lower Silurian [=Ordovician J, M. S.] of Central Asia (Tian'-Shan').

Some deposits of coal of Middle Devonian age are known in the U. S. S. R., for example, in Kazakhstan and Kuzbass. Excellent descriptions of the sapropelites (sapromixites) of the Devonian were given by M. D. Zalessky (1931) and Z. V. Ergolskaya. According to the opinion of the latter, they were formed from land plants of a simple structure (orestovia). Coals of the Upper Devonian are related to humic formations, and represent an accumulation of remains from a land flora.

Upper Devonian coal localities are more numerous than those of more ancient coal. Upper Devonian carbonaceous rocks and coal occur in the Voronezh region, on Bear Island, and also in Canada and on Ellesmere Island (Seward, 1936).

Thus, the formation of peat attained significant magnitude in the Devonian.

The Devonian flora of the U. S. S. R. has not yet been adequately described. The chief works are concerned with the ancient Devonian flora of the Urals, Middle Asia and Siberia (A. N. Krishtofovich, 1934; 1941); with the Voronezh region (P. A. Nikitin, 1934); with the Famennian stage of the Donbass (J. F. Schmalhausen, 1894; M. D. Zalessky, 1931b); with the Upper Devonian flora of the Balkhash (M. F. Neyburg, 1939); and with the Middle and Upper Devonian of Povolzhye and Zavolzhye (V. N. Tikhy, 1948); and also with the psilophytes of the U. S. S. R. (V. S. Peresvetov, 1951).

Fossil plants of the Devonian usually are represented in the form of impressions and phytoleims by shoots with sterile and fertile branches, leaves, sporangia, portions of coarse stumps, and bark.

Ancient Devonian floras occur in the U.S.S.R. at several places. A. N. Krishtofovich has described impressions of plants from the Urals and in Kazakhstan. He also described Asteroxylon sibiricum, Psilophyton princeps, Psilophyton sp., and Leptophleum sibiricum (Krishtofovich, 1927b; 1934) from the Minusinsk region of Siberia.

Krishtofovich (1938) found Duisbergia mirabilis in Kazakhstan.

V. N. Tikhy (1948) identified plant remains of Aphyllopteris sp., Archaeopteris cf. archaeotypus Schmal. (which is a characteristic representative of the Upper Devonian), and also Taeniocrada dubia Kr. et Weyl. (widespread in the Middle and Lower Devonian deposits of Belgium and Silesia) in sandy-silty strata of the Middle Devonian Givetian stage at Povolzhye and Zavolzhye. These plants have the appearance of long blades, covered with cuticle having a shagreened surface. According to Z. V. Ergolskaya, the presence of pores on the cuticle indicates a terrestrial life habit for these alga-like plants.

Fragments of the following plants were discovered at the base of the Frasnian stage in the Pashinskii series: Protopteridium hostimense Krejci, Hostimella hostimensis Pot. et Ber., Bothrodendron kiltorkense Haught., Archaeopteris aff. fissilis Schmal., Archaeopteris fimbriata Nath., Cyclostigma wukianum Heer. Similar forms of Archaeopteris were discovered at the village of Petino in the Voronezh region (Tikhy, 1948).

The largest quantity of plant remains was observed at the base of the Frasnian stage near Samarskii Luk; among them Archaeopteris aff. fissilis Schmal. and carbonized stems and bark elements of lepidophytes were particularly numerous.

Archaeopteris fissilis was described by Schmalhausen (1894) from the Famenian stage of the Donetz Basin. Later on the remains of some other plants, including Lepidodendrons described by M. D. Zalessky (1931b) under the name of Helenia, were reported.

Under the name of Callixylon M. D. Zalessky (1911) described woody material with mesarch protoxylem from Upper Devonian strata of the U. S. S. R. The genus Cordaites is cited from Devonian strata by some authors, but the so-called leaves are not proof that this genus actually existed earlier than the time when species of Cordaites were widely distributed in forests of the Carboniferous period (Krishtofovich, 1941).

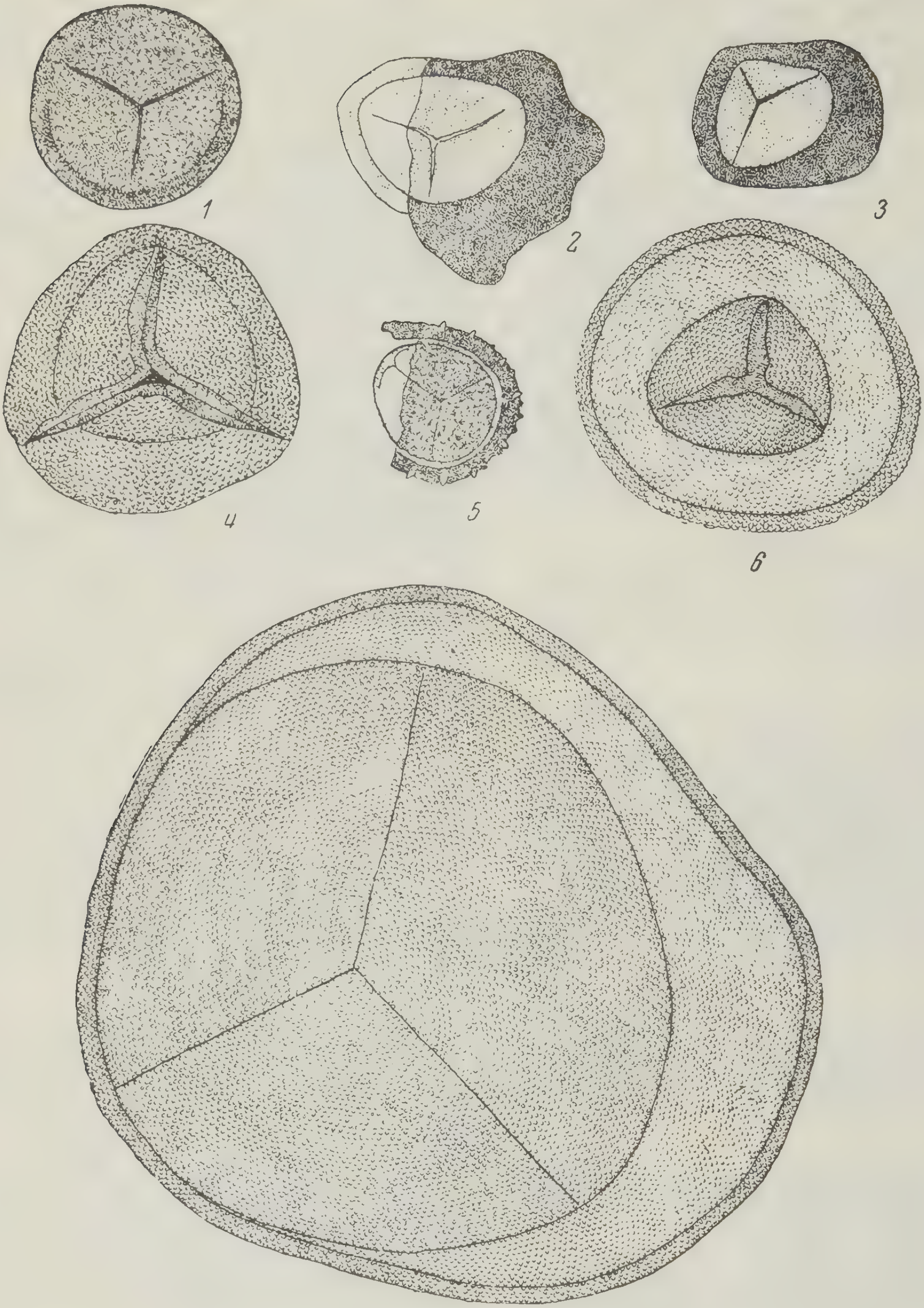

FIGURE 3. Spores with dense perines [perispores] of the subgroup Archeozonotriletes Naum.

1 - Spores from the sporangium of Sphenopteridium Keilhaui Nath.; upper Devonian, x 400 (after S.N. Naumova)
2,3 - Archeozonotriletes variabilis Naum., x 400
4 - Archeozonotriletes primarius Naum., x 400
5 - Archeozonotriletes fastuosus Naum., x 400
6 - Archeozonotriletes micromanifestus Naum., x 400
7 - Archeozonotriletes macromanifestus Naum., x 400

Generally it is the custom to distinguish sharply, on one hand, the flora of the Lower and Middle Devonian, which is represented by more archaic plants of the psilophyte type, from a considerably more highly organized fern-clubmoss flora, characteristic of the Upper Devonian, on the other.

However, in the opinion of A. N. Krishtofovich, which is confirmed by the latest finding of Archaeopteris in the Middle Devonian, substitution of flora began earlier, apparently in the Middle Devonian. It also continued in Frasnian time, as indicated by the mixed character of the flora of the Givetian stage.

For a long time the flora of the Devonian has been considered uniform but, in the opinion of A. N. Krishtofovich (1941), according to latest data it already showed climatic zonation. This has also been noted on examination of the spore-pollen composition in deposits of the northeast and of the central Devonian field.

CHAPTER II. GENERAL CHARACTERISTICS OF SPORES AND POLLEN OF THE DEVONIAN

The first investigations of Devonian deposits which were made by us in 1938 on the material of A. A. Dubyansky, showed a considerable diversity in the spores and pollen they contained. Later investigations fully confirmed these initial results and made it possible to isolate more than 1, 000 forms among the spores and pollen which are tentatively determined by us as "species" ["vid"].

Descriptions of more than 400 forms of spores and pollen, most of which occur as prevalent and guide forms for various series and layers of the Devonian (plates I-XIX), are cited in the present work.

The Devonian spore-pollen complex is mainly characterized by the development of spores of the groups Triletes R. of pteridophyte and bryophyte types, together with the pollen of gymnospermous type characteristic of the ancient conifers and cordaites.

Devonian spore forms are sharply distinguished in composition from the spore complexes of other systems by occurrence of spores with a well-preserved perisporium, both filmy and thick, of the sub-group Hymenozonotriletes Naum. and Archaeozonotriletes Naum.. These forms, as shown in Figure 3, belong to ancient types of fernlike plants like Protopteridium and Protolepidodendron.

Spores with a well-developed area[2], of the subgroup Retusotriletes Naum. (evidently belonging to the Marattiales, since spores of forms, such as Danaeopsis, are similar; see plate XIV, figs. 5-8), are widespread in the Devonian.

In addition, a considerable number of large spores of the subgroup Archaeotriletes Naum. are present. Spores of Azolla, the modern water fern, which are provided with large, long spinelike protuberances with enlarged bifurcated ends, as shown in Figure 2, are similar in type. Small examples of this type of spore are described by me from deposits of the Lower Silurian [Ordovician J. M. S.] of the Baltic area (Naumova, 1950).

Spores of the subgroup Brochotriletes Naum. with alveolar sculpture, and of the subgroup Dictyotriletes Naum. with net reticulation, which belong to the clubmoss type of plants, are individually encountered.

Also, an insignificant number of spores with narrow bodies of the subgroup Stenozonotriletes Naum., and individuals of Camarozonotriletes Naum., which have an extensive development in the Mesozoic, were observed.

The remaining spore forms, which have simple sculpture and lack a border, are related to the subgroup Leiotriletes Naum. Round, folded forms of the calamariaceous type predominate. Trachytriletes Naum., Acanthotriletes Naum., and Lophotriletes Naum. are present. In general, these subgroups are widely distributed in other systems. Many forms occur among them that have an extended vertical distribution; others are restricted to the Devonian, to only one of its stages, to several suites or, exceptionally, to only one suit of beds.

The pollen of gymnosperms is represented by an insignificant number of forms with limited vertical distribution in Upper Frasnian deposits. They include a small number of forms of the subgroup Archaeoperisaccus Naum. (ancient conifer type), and the subgroup Perisaccus Naum. (cordaitean type).

CHAPTER III. THE MORPHOLOGY OF DEVONIAN SPORES AND POLLEN

Spores of modern plants have three membranes: the inner, called the intine or endospore; the outer, the exine or exospore; and, in some plants (Polypodiaceae and others), spores also are enclosed in a special membrane, the perisporium, which is generally filmy in the spores of modern plants.

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[2] Area: the contact surfaces of spores in the mother cell, on which the tetrad scars remain. In some forms this part of the surface is thickened or depressed in a three-sectioned semi-circular configuration.

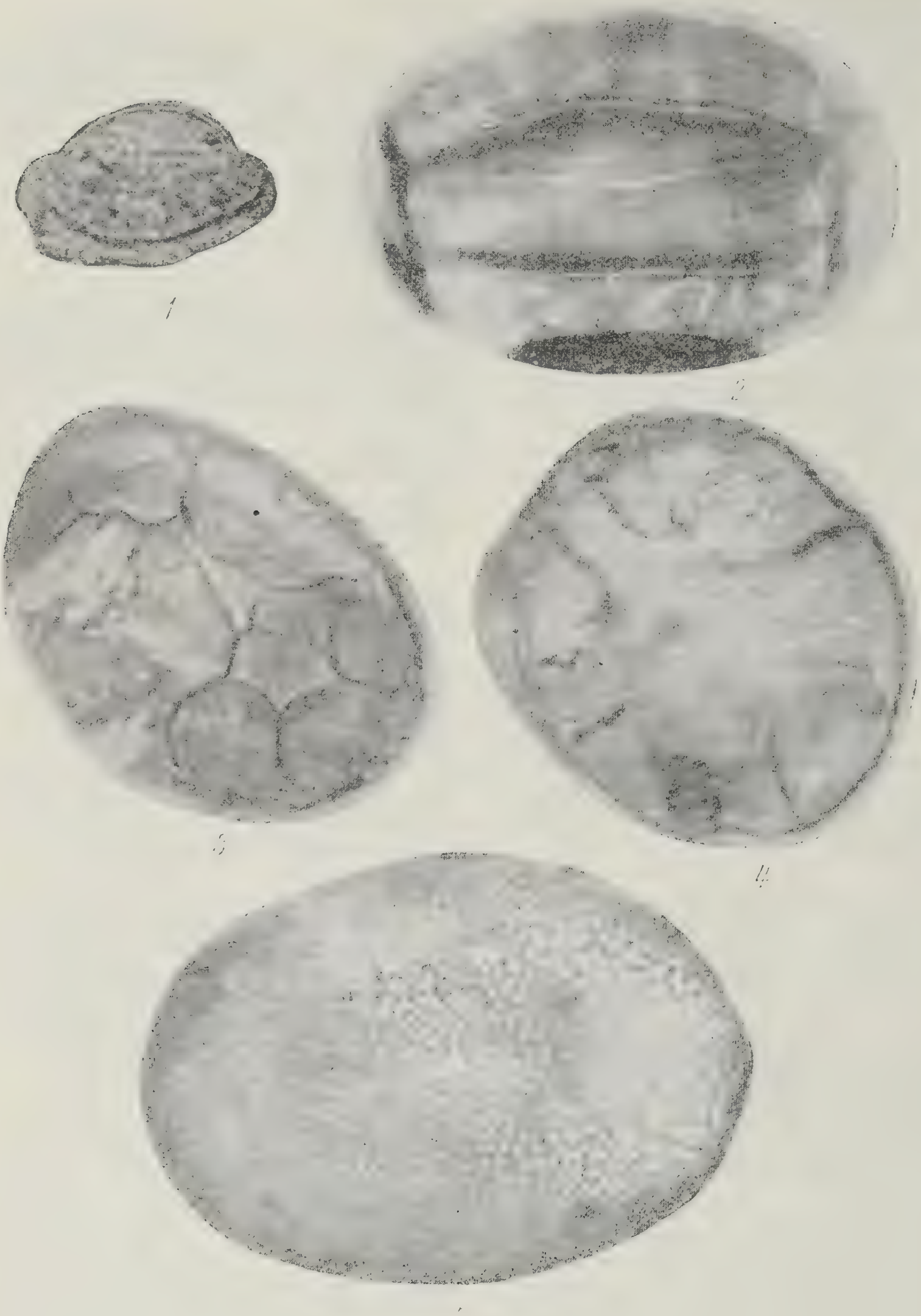


FIGURE 4. Gymnosperm pollen.

1- Pollen of the contemporary Pinus silvestris, x 500 (after G. Dubois).

2- Pollen of the Pteridosperm Goldenbergia glomerata Hall; middle Carboniferous, x 240 (after G. Galla).

3,4- Pollen of the Cordaite Stephanospermum akenoides Br.; middle Carboniferous, x 400 (after G. Galla).

5- Pollen of the Cordaite Cordainthus; middle Carboniferous, x 400 (after R. Florin).

Only the exine and perisporium are preserved in fossil state. These membranes are composed of an extremely stable substance, which is closely related to cutin. The intine and inner cellulosic contents of the spore ordinarily undergo complete disintegration.

In the Devonian, in contrast to other systems, a greater proportion of the spores have a well-preserved, dense, thickened, or filmy and variously sculptured perisporium in which the exine is enclosed. The exine, in turn, also has definite sculptural characteristics.

Devonian spores and pollen are distinguished by a great diversity in size, outline, structure of both the exine and the perisporium. As in other systems, the color of Devonian spores and pollen varies from light yellow to dark red. Spore color depends on the following causes:

1. Thickness of exines and perisporium. Thickness is closely related to the ecological type of plant; thinner or thicker, but friable, exines are characteristic of spores and pollen of hydrophilic and mesophilic plants; spores and pollen of more xerophylic plants have more massive and denser exines.

2. Weathering. Spores that occur in sediments long exposed to weathering (such as those represented by the central part of the Pestrotsvetni layers) have darker coloration, and some of them are completely opaque.

3. Character of maceration. Submacerated spores are red in color or completely opaque. Overmacerated specimens, on the contrary, are lighter in color with sculpture only vaguely expressed.

Spores and pollen of the Devonian vary in size from 10 to 1200 microns; most of the forms range from 20 to 70 microns. The size range of spores and pollen of individual species within one bed [tolshchi] is relatively constant and the variation is insignificant. Apparently, other morphological features being identical, this variation is a function of the degree of maturity, except in spores of heterosporous plants, whose microspores are 20 to 40 microns in diameter and whose megaspores attain 100 to 1200 microns. Both simple and complex structural types of spores are present in the Devonian. For example, smooth and folded spores of the Calamariaceae are of the simple type; spores of Archaeozonotriletes macromanifestus Naum. and Archaeozonotriletes micromanifestus Naum. are of the complex structural type. At the same time, size of spores and pollen shows considerable variation in various strata depending on the conditions of deposition.

We succeeded in determining a regular stratigraphic sequence of changes in size for some forms of Devonian spores and pollen. These changes are connected with evolution of the particular form of plant; i. e., with the time of its origin, dispersal, and extinction. For example, the spores of Retusotriletes Naum. first appeared in the Lower Devonian, where their size did not exceed 10 to 15 microns. In the Middle Devonian they reached their maximum size of 60 to 70 microns and became the predominant form, as shown in Figure 6. In the Upper Devonian these spores had a diameter of 30 to 40 microns and, in the Tournaisian stage of the Lower Carboniferous, their size dropped to 10 to 15 microns.

The same regularity is observed in some spores of the subgroup Hymenozonotriletes Naum., which are at a minimum size at the beginning and end of their range of existence, and attain maximum diameter in the middle of their range at the time of culmination (in Upper Frasnian deposits).

The range in size of some spores and pollen also is related to ecological conditions affecting growth of the plants. Thus, one observes a decrease in size of some spores belonging to one and the same form, according to change in type of deposit from continental to marine. Evidently this decrease in size is related to a deterioration of conditions during the period of existence of plants in a more humid climate (as in the Pskovskian beds).

The outlines of spores and pollen are principally round, rounded oval, rounded triangular, and triangular. A rounded outline is characteristic of the more primitive forms and a triangular outline of the more advanced ones. The pollen of pteridosperms has an ellipsoidal outline.

The sculpture of Devonian spores and pollen is extremely varied. Their exine and perisporium have, for the most part, primitive sculpture--smooth or shagreened, with diverse spines and granules. One hardly ever finds reticular, alveolar, and costate sculpture with a narrow selvage [otorochka], as in more complex examples.

Sculptural features of the exine or perisporium of spores and pollen are related chiefly to the systematic position of the plants with which they show affinity. At the same time sculptural features are closely dependent on conditions under which the plants developed. In addition, the sculpture is dependent on the degree of maturity of the spores and pollen at the time of deposition. This determines to a large extent the distinctness of their sculptural features.

According to our studies of modern vegetation, the greatest variation and individuality

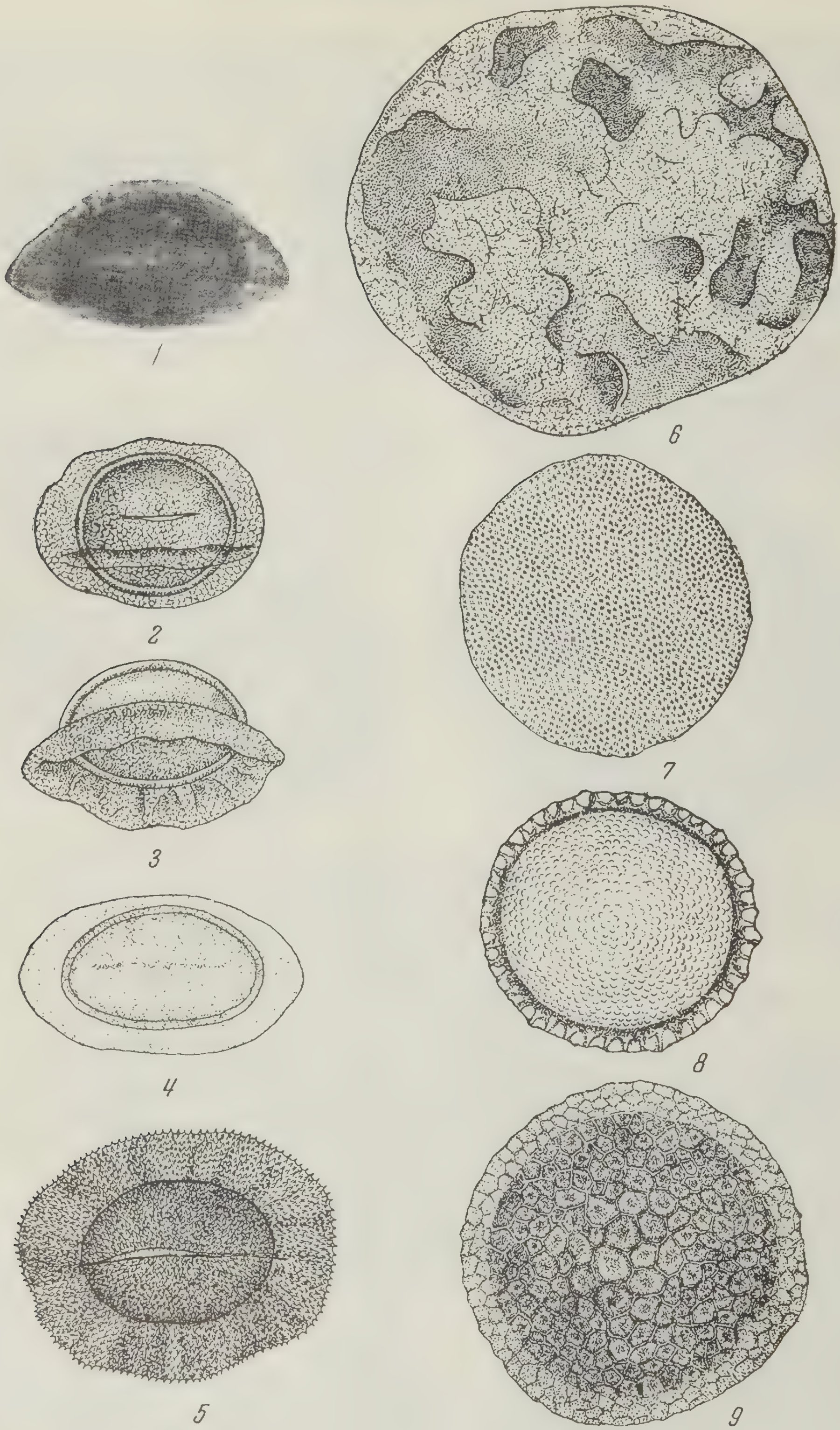


FIGURE 5. Pollen of the upper Devonian Gymnosperms

1-5 - pollen of Gymnosperm type, x 400

6-9 - pollen of Cordaites type, x 400

of sculpture of spores of pollen grains has been achieved by land plants. In these forms it is well expressed, as in Dicksonia and others shown in Figure 1. Spores and pollen of moisture-loving plants, fern-like as well as angiosperms, aquatic plants in particular, such as the Hymenophyllaceae, Calamariaceae, Potamogeton, Sparganium, and others, have uniform, poorly expressed, often reduced sculpture.

In some aquatic plants exines have completely disappeared, as in Ceratophyllum. The relation of the exine to the type of plants is observed among the large, woody and small ferns. Woody ferns, such as Alsophila and Dicksonia, have spores with a very dense exine and prominent sculpture, while the spores of small ferns generally have delicate exines and inconspicuous ornamentation, as in the Hymenophyllaceae.

Thus, given similar ecological conditions, the sculptural features of spores and pollen assume a similar appearance. In aquatic plants this results in a simplified character; in land plants the structure is more complex.

The character of sculpture also depends on the stage of maturity of spores and pollen. Thus, spores in a single stratum show varying degrees of development of sculptural features, depending on individual differences in maturity of examples from a single plant at the time of burial.

Variation in sculpture of spores and pollen through geologic time is dependent on two causes: first, on evolution of a given form of plant, and second, on change of habitat. In the first, as well as in the second instance, sculptural changes are quite evident among spores having complex sculpture, but such changes are only shown by an increase or decrease of size in spore and pollen forms with simple sculpture (see fig. 6). Lophozonotriletes Naum., for example, illustrates the following changes within stratigraphic sections of the Frasnian stage: In the lower parts of the Shchigrovski beds spores of this subgroup occur individually and are small, with sculptural features poorly expressed; the spores have small protuberances which are not clearly outlined. In the Petinski beds, where forms of this subgroup are dominant, the spores are very large and have a well-developed sculpture with large protuberances which are sharply outlined, as shown in Figure 6. In this instance it is necessary to know the morphological history of evolution of the spores and pollen.

At the time of new appearance of a group or subgroup, and especially at the time of culmination, which is shown by extensive horizontal and vertical distribution, a greater variety of similar, or morphologically comparable, forms of spores and pollen may be observed. The period of extinction is marked by diminished variety in groups that are more sharply defined and distinct, with isolated or sporadic representation.

CHAPTER IV. BOTANICAL AFFINITY OF SPORES AND POLLEN IN THE DEVONIAN

Botanical identification of spores and pollen in the Devonian is made in two ways: first, by comparison of fossil spores with spores of modern plants; second, by comparison of fossil spores with spores taken directly from the reproductive parts of fossil plants.

The botanical identification of spores and pollen of the Cenozoic deposits, where all or nearly all of the plants are represented by modern genera, usually is made by the first method.

Spores and pollen of older deposits, where most of the plants are assignable to extinct groups, usually are identified by using the second system. For Devonian deposits, there is a further complication since plant fragments here are found rather rarely, have been little studied, and most of them are identified from fragments of shoots or, more rarely, leaves. True systematic assignment of most of them at this time is not clear, since they are now generally classified in artificial groups. In addition, decisive boundaries are not established between the fragments of fern-like plants, some of them being referred to ferns and some to pteridosperms.

Our investigations show that Devonian spores have a cutinaceous membrane and tetrad ridge, characteristic of the modern spores of Pteridophyta and Bryophyta.

In order to relate Devonian spores and pollen with groups of plants we have studied the literature, which is scanty and dispersed, but extremely important. We have also studied personally spores obtained from sporangia of Devonian plants. These studies have allowed some advances to be made in systematic association of spores, even though assignment is limited to large taxonomic units (groups, etc.).

Evidently large spores and small, smooth with round outline and folds, belong to the calamariaceous type. Similar spores from the stone coal [Carboniferous] were studies by Hartung (1933) from carbonaceous spore-bearing parts of Calamostachys and Palaeostachys. However, similar smooth spores without wrinkles were discovered by Kidston and Lang in sporangia of Sporocarpon furcatum Daw. from the Upper Devonian of America. They refer S. furcatum to the simplest land plants, as yet of unknown systematic position

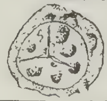
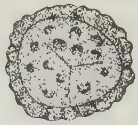
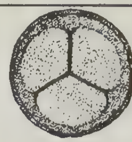
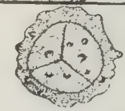
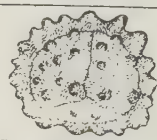
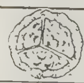
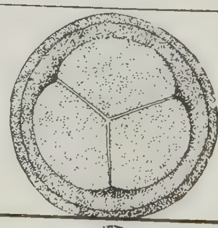
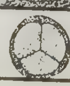
Stage	Formation	No. of complex	Lophozonotriletes Naum.	Retusotriletes Naum.
C_1^1	Malevka-Murayevna			
D_3^2	Dankov-Levedyan	II		
	Elts	III		
D_3^1	Evlanovo	VI		
	Voronezh	VII		
	Petino	VIII		
	Semiluki	X		
	Shchigrov	XII		
		XIV		
D_2^2	Staryy Oskol	XV		
D_2^1	Ryashsko-Morsov	XVII		
D_1		XIX		

FIGURE 6. Morphogenesis of Devonian spores

(Kidston and Lang, 1924-1925).

Spores with small, curved spines of Acanthotriletes acerosus Naum. belong to the group Articulatae. Similar forms were separated by Moore from sporangia of the Carboniferous Sphenophyllum (Moore, 1946).

According to A. F. Nikolayev, Marattiopsis has small spores with wrinkles and fine spiny sculpture.

Spores of the subgroup Archaeotriletes Naum. with large and long, pointed bifurcate spines (branched terminations) resemble spores of the modern water fern, Azolla (see fig. 2).

According to Moore (1946), a filmy perisporium is characteristic of spores of the Sphenopteris type of plants which are related to pteridosperms in the Carboniferous. According to E. M. Knox (1938), the filmy perisporium also occurs on modern spores of Selaginella and in the Lycopodiales. Spores of the subgroup Lophozonotriletes Naum. are similar to spores of the ancient fern Alsophila (S. N. Naumova; see fig. 1).

Spores of the subgroup Archaeozonotriletes Naum., with a filmy perisporium, were discovered by me in the sporangium of Sphenopteridium Keilhaui Nath. (identification by M. F. Neuberg) collected by S. V. Tikhomirov from the Cerezov beds of the Upper Frasnian deposits (fig. 3).

The Upper Frasnian pollen of the subgroup Archaeoperisaccus Naum. is similar to pollen of the Carboniferous pteridosperms described by Halle and Florin from reproductive organs of Whittleseya and Aulacotheca (Halle, 1933). Pollen of this type resembles a filmy, shagreened, coniferous sack, sometimes with a longitudinal fold in which a dense, oval body with a single aperture was included.

This group of pollen resembles that of woody conifers in morphological features. This type of pollen also occurs in Permian deposits and possibly represents ancestors of the Pinaceae (see fig. 4).

Spores of the subgroup Perisaccus Naum. are analogous to spores of Cordaites described from the Carboniferous spore-bearing parts of Potoniea Carpentieri (Kid.) Halle, and Whittleseya elegans Newberry (Florin, 1936, 1937).

Similar spore forms were found by us in the Carboniferous and, in particular, within Lower Permian deposits.

Principally microspores have been investigated in the present work because they are present in large numbers and numerous forms are represented; a few megaspores are included. The megaspores most clearly demonstrated are characterized by a thick porous grained perisporium with very long, thickened protuberances of the Kryshtofovichia africani Nik. type. The megaspores are relatively common in Devonian deposits, but they are less diversified than the microspores, and up to now their stratigraphic significance has not been elucidated.

CHAPTER V. CLASSIFICATION OF DEVONIAN SPORES AND POLLEN

The majority of the Devonian plants, to which the spores studied by us belong, are represented by not only extinct genera, but also by extinct families and classes. Very few of the leafy impressions of fern-like plants of the Paleozoic lend themselves to natural classification and, for practical purposes, most of them long since were arranged in an artificial classification according to a series of morphological features (shape of fronds, subdivision, veining, etc.).

In such a classification closely allied forms sometimes fall into groups remote from one another; on the other hand, types having an entirely different origin and systematic position may fall within a single genus (Krishtofovich, 1941).

However, since there is no alternative, as A. N. Krishtofovich shows, for the present, at least, one cannot dispense with the use of the artificial system. This system provides a means of distinguishing the forms of impressions and of characterizing various horizons. Regardless of anything a name implies, this is all dictated by purely practical objectives.

"Assemblages of the Paleozoic ferns are further complicated, according to the artificial system, by the fact that we have undoubtedly recognized some cycads and bennettitae among them which cannot be distinguished from ferns by the character of their fronds" (Krishtofovich, 1941).

The phylogenetic treatment of classification of Paleozoic spores and pollen presents even greater difficulty, since plant impressions with reproductive organs, from which it would be possible to study spores for comparison, are even more rarely encountered than vegetative material.

Accordingly, classification of spores and pollen must still be based, for the most part, on morphological principles that take into account only the characteristics of large systematic groups in the natural system.

In the present work the classification of

spores and pollen developed by me (Naumova, 1937), and somewhat supplemented in recent years, has been adopted. This classification is based on genetic and morphological principles. Thus, large taxomomic units, such as orders and classes of spores and pollen, are grouped in a natural classification. With the exception of certain units attached to plants, the smaller taxa, such as the group (family) [grup (semistvo)] and subgroup (genus) [podgrup (rod)] are, for the most part, morphologically classified.

The essential criterion, which serves as the basis of classification of spores and pollen, is the presence and character of the aperture, by means of which spore and pollen germination occurs.

Spores of the pteridophytes are distinguished, according to the type of tetrad formation, by a triradial (Triletes R.) or by a uniradial aperture (Monoletes Ibr.).

Spores with a triradial aperture are characteristic of the majority of modern Pteridophyta and Bryophyta. Spores with a uniradial aperture occur only in some ferns of the polypodiaceous type.

Further subdivision is carried out by reference to morphological features.

Groups are differentiated depending on the presence or absence of a selvage [otorochka]; e. g., presnet in Zonotriletes W., absent in Azonotriletes Lub..

Subgroups of spores, which correspond to the genera of a natural classification, are identified according to their sculptural characteristics.

Accordingly, the group Azonotriletes Lub. is divided into the following subgroups: Leiotriletes Naum., surface smooth; Trachytriletes Naum., surface shagreened; Acanthotriletes Naum., surface spiny; Lophotriletes Naum., surface tubercular; Dictyotriletes Naum., surface reticulate; Archaeotriletes Naum., spines with thickened, bifurcate ends; and Retusotriletes Naum., with prominent contact areas.

The group Zonotriletes W. is divided into nine subgroups, of which only five occur in the Devonian: Archaeozonotriletes Naum., spores with a thick perisporium, projecting as a selvage [otorochka] around the edge; Hymenozonotriletes Naum., spores with a filmy perisporium, projecting along the edge as a membranous selvage [otorochka]; Stenozonotriletes Naum., spores lacking a perisporium, with a narrow selvage [otorochka]; Lophozonotriletes Naum., spores with a thick perisporium and large protuberances along the edge; Camarozonotriletes Naum., spores in which the selvage [otorochka] is only developed on the sides, disappearing on the corners, as is characteristic of some spores of modern plants of the cyatheaceous type.

Gymnospermous pollen is represented in the Devonian by two subgroups: Archaeoperisaccus Naum., pollen with one oval air sac, in which an oval body is enclosed; Perisaccus Naum., pollen with one round sac, body enclosed within (see fig. 5).

The differentiation of subgroups [podgrup] into species [vid] is by minor features; for example, distribution of protuberances, size of the spines, protuberances, etc.

Species [vid] of spores and pollen in themselves present a definite historical sequence of morphological evolution, dependent on changes in conditions of growth of the original plants; but they definitely are not equivalent to the concept of plant species in general.

Obviously, the differentiation of groups in a provisional morphological classification can, and probably will, cause numerous problems. The ease of subsequent transition to the natural classification will depend on an accurate evaluation of the systematic significance of criteria that now serve as the basis for the artificial system.

Because of this, it is scarcely possible within the frame of morphological classification to differentiate correctly numerous individual genera on the basis of features which do not possess great systematic meaning (form of body, outline, etc.). Although at first glance it seems to facilitate the systematization of material, such a practice actually presents great difficulty since it diverts investigation onto a clearly formal road of description, of a particular type, under different names.

This greatly complicates the transition from artificial classification to the subsequent natural system, an ideal which all paleobotanical investigations should, in the end, strive to achieve.

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NATURAL GEOGRAPHIC DATA OF NORTH CHINA, GEOMORPHOLOGY[1]

by

K'o-hsueh Ch'u-pan-she

- prepared by U.S. Joint Publications Research Service -

ABSTRACT

North China is divided into three major geomorphic regions. Thick deposits of loess are a primary feature of the area; its distribution, age, and relation to other geologic formations are given. The Variscan and Himalayan orogenies influenced the paleogeography of the region greatly. The Huang Ho deposits great amounts of silt annually; efforts to control this river constitute a continuing major effort. --M. Russell.

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INTRODUCTION

Generally speaking, North China lies between 32° and 43° north latitude; in the northwestern part it comprises loess plateau formations and the Hopeh-Jehol mountain regions, in the southeastern part it includes the Shantung-Liaotung rolling country, and in the center it covers a vast area, the great plains of North China and the lower course of Liao Ho. This region borders on the Yellow Sea and P'o Hai in the east, extending from the estuary of the Yalu River on the northeastern boundary along the An-shen [An-tung-Mukden] Railway to Ssu-p'ing-shih, proceeding further from the southern edge of Fen-shui-ling in the Sung-liao area toward T'ung-liao, there terminating in the vicinity of the northwestern region; in the north it proceeds westward toward the primary divide in Jehol in the direction of the southern fringe of the lava plains at Chi-ning after traversing the Ku-yuan shores, continuing along the Great Wall across the southern edge of the O-erh-to-ssu plateau; in the west it encounters the east end of Ch'i-lien Shan on the border of the Mongolian tableland; the western border lies approximately at 103° east longitude, rising irregularly to a [maximum] height of 3, 000 meters above sea level and separated from the plateaus of Ch'ing-hai and Tibet; in the south it borders on the northern ridges of Ch'ing Shan, which penetrate into Shensi from Kansu, forming Fu-niu Shan and Ta-pieh Shan intermittently at the eastern terminus. At the east end of the southern border lies Huai Ho, which extends to the north of Ta-pieh Shan.

The natural characteristics of this region are determined by its mid-latitudinal location and by its position on the fringe of the east oceanic trade wind belt. It is severely cold, clear and dry in winter, the area being strewn with dust carried by northwest prevailing winds. In the summer there is a period of unbearable heat followed by an abundance of rainfall, decreasing in amount as one goes from the coast toward the interior in a northwesterly direction. This great expanse is dotted with green areas in summer, thus reflecting the influence of oceanic moisture on the rolling country along the coast and the mountains in the interior. In the clay-covered region to the northwest where there is little precipitation dry prairies have developed. From east to west this region changes from forested areas to grasslands, the soil content turning from brown forest clay to dark brown and calcium-laden earth. In this area where Chinese agriculture developed early, the soil was continually exploited and crops were cultivated [regularly] by the inhabitants, thus causing tremendous changes to occur in the terrain. The river beds are [now] blocked and silt has accumulated as loess and soft, loose weathering substances are swept off by the summer torrential rain toward the lower reaches where catastrophic floods take place frequently. Situated as it is on the summer wind belt, precipitation is irregular and unstable, giving rise to frequent droughts. Hence, all endeavors at improvement in the field of economic reconstruction must take into account these natural phenomena and must concentrate on corrective measures.

Nevertheless, one should not be blind to the potentially productive elements that prevail in this region. As its warm season exceeds six months and as its precipitation is suitable for cultivation requirements, agricultural production of wheat, millet, corn, cotton, etc., has thrived in this region. By far the largest portion of this area is covered with rich dark brown virgin soil which would be suitable for agriculture if only irrigation were introduced. This area, characterized as it is by a vast tract of great plains, is also well adapted to mechanized agriculture. Richly endowed with hidden natural resources such as coal and iron ores and, particularly petroelum and oil shale in the north Shensi area, this region possesses the necessary prerequisites for the development of heavy industry. Added to this

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[1]Translated from Hua-pei-ch'u Tzu-jan Ti-li Tzu-liao [Natural geographic data of North China]: Sections of Introduction and Geomorphology, p. 1-23, Peking, Dec. 1957. JPRS trans 1002-N in part.

is an abundance of hydraulic power which in the future may be harnessed for electric power as a substitute for coal, thereby eventually serving as a principal raw material for the development of a chemical industry. The potential for agricultural growth in North China is beyond comparison. With the exploitation of natural factors and the organization of agricultural enterprise under socialist principles, agriculture and communications in North China are being electrified and mechanized, and its waterways will be drawn upon to furnish necessary hydraulic power for the production of electricity. Judging by its potentiality in this respect, it is no exaggeration to say that planning in this direction is perfectly feasible [1].

Marked by rather distinct natural features, this area may be subdivided into auxiliary regions to facilitate the examination of its geographic characteristics.

Loess Plateaus and the Hopeh-Jehol Mountainous Region

This subregion lies in the extreme north. Located near the center of loess formation, the tract is extensively covered with a deep layer of loess. It is rich in calcium content, and this richness has been intensified by the dry climate prevailing in that region; however, due to the decomposition of vegetation the [content of the] top clay layer has been modified. Aggravated by climatic extremes, the loess cover has turned into claylike immature virgin soil or subsoil, whereas the unused topsoil is strewn with grass and plant life. The mountains are extensively covered with brownish clay, indicating that they had been previously forested. Woods may still be observed here and there in secluded areas or on top of lofty mountains. Rich coal resources lie hidden in loess-covered plateaus where petroleum, oil shale, and gypsum deposits are found in great quantity. The Hopeh-Jehol region, like Ta-t'ung, Pei-p'iao and Fou-hsin districts, is not only a cradle for rich coal deposits but also a storage center for the world famous "lung-yen" [literally, dragon-smoke] iron ores. This region is indeed richly endowed. In harnessing the forces of nature, moisture preservation and soil improvement are problems of the first magnitude. Such improvements are bound to have repercussions in adjacent regions. If silt now accumulating in this area can be eliminated at the source, the great plains of North China will assume a new appearance in respect to agriculture and water conservation.

The Great Plains of North China and Liao Ho

The great plains consist of layers of accumulated silt, and their sources may be traced back to the upper reaches of Liao Ho and the mountain valleys of the tableland. With the exception of the southern Huai Ho region and isolated coastal areas where the soil is contaminated by alkalis, the great expanse of this area is covered with dark brown and yellowish-brown clay. The great plains are surrounded by mountains containing rich seams of coal; they are suitable for mining as well as agriculture. In the first subregion where the clay cover has been washed away and where waterways had been blocked by the silt thus deposited, the area has been denied the advantage of free unhindered navigation. These natural and man-made factors are responsible for the recurrence of drought and flood, and the extension of the alkaline zone endangers agricultural production and threatens the security of the people's livelihood. The Huai Ho and Hai Ho waterways are being dredged and Huang Ho is also undergoing large-scale conservation work. If loess conservation problems in the plateau areas are solved in the near future, natural disasters such as drought and flood will be kept under control, and the alkaline content of the soil will be decreased. If superior Soviet agricultural methods are adopted, farm production would increase greatly and this region would become China's richest granary.

The Shantung and Liaotung Rolling Country

These coastal regions, having been subjected to oceanic climatic influences, have lost their continental characteristics. At one time, the region was thickly wooded with broad-leaf and needle-leaf trees, and forests grew on a layer of brown clay. However, after a period of sustained deforestation, the wooded area had almost disappeared and the mountains now present a severely despoiled appearance. Fruit culture and sericulture are the principal occupations for the inhabitants of this area, although it is richly endowed with coal and iron deposits. In addition, there are aluminum and valuable gold deposits. The coastal area is characterized by bays, indentations and archipelagos, suited to the pursuit of fisheries and the salt industry. Exploitation of hidden wealth, reforestation, water and soil conservation, and development of fruit culture and of the fishing industry are the major economic tasks to be performed [2].

GEOMORPHOLOGY [2]

Topographic Features

The natural precincts of North China comprise loess plateaus, North China plains, the Hopeh-Jehol mountain regions, the Liao Ho plains, and the Shantung and Liaotung rolling country, all marked by the following features:

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[2] Charts and maps appearing in this book were drawn by Comrades HUANG Chien-hsu and HSU Ch'i to whom thanks are due.

Prevalence and predominance of stratiform [?] features

North China is based on Chung-ch'ao-lu-tai.[3] While Lu-tai is comparatively stable and firm, Chung-ch'ao-lu-tai is characterized by mobility and instability. Lu-tai is marked by moderate broad convolutions rather highly stratified. For example, the eastern slope of Tai-hsing Shan and the northern slope of Ch'ing-ling are marked by several hundred meters of strata lines with precipices rising to a dangerous height of from several hundred meters to a thousand meters. Loess plateaus to the west of Tai-hsing Shan are highly stratified. The banks of Fen Ho and Wei Ho and their valleys are stratified. North of Yen Shan the Hopeh-Jehol mountainous region is dissected by parallel and transversely positioned strata and carved out into elevations and basins in a labyrinth of mountain ranges. Further to the east the Liao Ho plain is located within a stratified mountain range running toward the southwest from the northeast. The Shantung and Liaotung rolling areas are also characterized by strata. T'ai Shan and I Shan are shaped like an inverted basin. The Ta-fen Ho fault trough south of T'ai Shan penetrates directly into the heart of the Shantung mountains.

The formation of faults is still proceeding, for recently created triangular-shaped fault scarps[4] may be observed on the northern slope of T'ai-ku (Shansi) and Hua-shan (Shensi). Here earthquakes are frequent, causing the terrain to be thrown into fault troughs. Violent quakes in central Kansu brought great calamities in their wake. (fig. 1).

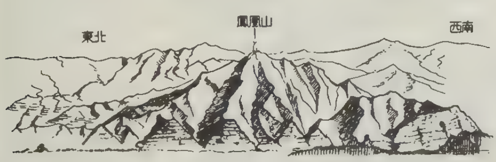

FIGURE 1. Triangular-shaped fault scarp at T'ai-ku extending from the southwest to the northeast with Triassic red sandy shale dipping 5° north.

[3]Chung-ch'ao and Lu-t'ai mentioned in the above paragraphs refer to stabilized areas formed during the Precambrian era, whose characteristics and scope are indicated in CHINA'S PRINCIPAL GEOLOGICAL STRUCTURAL UNITS, 1945, written by Huang Chi-ch'ing.

[4]Triangular-shaped fault scarps are newly developed features. As they rise streamlets and brooks continuously sink, and V-shaped valleys are formed between towering precipices and cliffs. The slopes in the valley form an inverted V-shape. Judging by their stratification [?] such features must have been formed recently [3] .

Extensive loess cover and its distinct topographical features

This area is extensively covered with Quaternary loess, widely distributed over an area comprising Shansi, Shensi, and Kansu and also the southwestern section of Honan. Plateaus and mountain valleys are blanketed with loess to a depth of from 20 - 30 to more than 200 meters. Hence, they come to be known as loess plateaus.

In northwestern Hopeh and Jehol, basins and elevations among the mountains are covered with loess to a depth of over 10-30 meters. Few patches of loess-covered areas are observed west of Liaotung and north of the Shantung rolling country. Loess-covered lots are scattered among highlands in the middle and upper reaches of Huai Ho. Rivers over north Chinese plains are clogged with silt composed of loess. (fig. 2).

In physical properties loess is loose and smooth; it stands in vertical slopes. Where erosion occurs lumps of clay collapse along such perpendicular cleavages, thus accounting for the formation of steep cliffs. On the border of loess-covered regions are found networks of valleys whose depth ranges from several meters to 300 meters. In respect to their density, a single valley may extend for many kilometers or many valleys may lie within an area of one kilometer. Where the valleys are found clustered together, the terrain is dissected into elevated regions of irregular height.

Accumulation of silt

Apart from the fact that loess is continually being washed away over a vast area, this region and other areas whose faults are composed of Quaternary loess and Tertiary laterite are very susceptible to erosion because loess is low in adhesive strength. Rivers had been formed long before loess had accumulated, penetrating far into the heart of loess-covered tablelands which rise to great heights. Because of precipitation, imperfect methods of cultivation and other destructive influences, erosion has been proceeding at an accelerated pace on the highlands. In some extreme cases an annual loss of 0.5 to 1.0 meters in the depth of loess has been ascertained[5]. Rivers in this region contain a great deal of silt. For example, the average annual carrying capacity of Huang Ho and Yungting Ho is placed respectively at 1.38 and 0.2 billion cubic meters of silt which literally pile up over tracts of lowland on the coast, thereby building up vast plains. Wells may be drilled

[5]Lo Lai-hsing, Chi Yen-nien. EROSION AND ITS EXTENT AT WU-TING HO AND CH'ING-CHIEN HO IN LOESS REGION SHENSI, V. 21, no. 1, Geographic Review (4).

FIGURE 2. Distribution of loess in North China

to a depth of several hundred meters without hitting bed rock, indicating that deep layers of clay have accumulated. The triangular delta area at the estuary of Huang Ho annually extends further into the sea by several tens of meters. The depth of P'o Hai has shrunk. There is no doubt that the rate of erosion and the speed of accumulation find no parallel in the natural history of China.

A Brief Sketch of Ancient Geological Development

Land foundations in North China were formed in the historic time of Chung-ch'ao and Lu-t'ai. At the belt of highlands encircling the great plains of North China (Shansi-Jehol, Shantung-Liaotung and Ch'ing-ling Ta-pieh Shan) the rocky formations had undergone visible changes in quality, yielding spitted surface shale [porphyry ?], crystalline schist, granite-gneiss (Archaean), quartzite, sandy limestone shale, slate, phyllite, etc., (including Hsuan-hua type iron ores of the Sinian Period (fig. 3).

Due to a protracted period of exposure, the highlands had been repeatedly leveled off and had risen to new elevations. They are now elliptical in shape (Shantung), and plains have emerged (on the borders of Kiangsu, Shantung and Anhwei) where erosion was severest. At a later period some areas rose to tremendous heights (Wu-t'ai Shan, Lu-liang Shan, T'ai Shan, etc.) where visible marks are preserved on the peaks. Transfigured [metamorphic ?] limestones that gained hardness and density in the past are now scattered over a wide area composed of Precambrian rock formations, showing rows of tooth-shaped peaks together with sandy limestone formations of the Sinian Period.

Great portions of this region such as loess plateaus and mountainous terrain in the great plains of North China and Liao Ho are composed of thick layers of lime shales of the Cambrian and Ordovician periods, indicating that these portions of the Sino-Korean platforms had submerged in the sea during the Pre-Paleozoic Era, with the exception of a portion of land to the northwest of Jehol, Chiao-tung and Liaotung (fig. 4).

Silurian and Devonian faults have not been accounted for in the available records on prehistoric stratification [?]. Probably the entire North China area emerged from the sea after the Ordovician when erosion proceeded at an increased rate, leaving in its path a residue of iron ore deposits (mainly distributed over Shansi).

During the latter part of the Paleozoic (Carboniferous and Permian periods), shallow seas and lakes came into being as the terrain rose. Also the coastal region became thickly wooded. Thus, areas in north Shensi, east Kansu, southeast Shansi, southeast Shen-yang [Mukden], Shantung and Honan, and the Western Hill in Peiping are endowed with rich coal deposits (fig. 4, II).

In respect to location, the land basins of the Mesozoic correspond closely to the shallow sea and lake regions. After a period of dry climate the basins were filled with salt-saturated or gypsiferous sandstone and shales (as illustrated by the gigantic land basin of north Shensi containing petroleum deposits of the Triassic). Plant life had thrived because of moisture made available through coal strata of the Jurassic. The coal deposits of Ta-tung (Shansi) and Po-shan (Shantung) and those of Fou-hsin (Jehol) were formed during this period.

The Yen-shan orogeny which basically determined the topographical features of this region took place at the end of the Jurassic but before the Cretaceous, causing the formation of colored ore beds. This movement was responsible for the alteration of topographical features to southwest from northeast (an alteration from east northeast to north northeast), varying in degree with different localities. At Western Hill (Peiping) and T'ai-hsing Shan and Shansi plateaus, broad anticlinal and centroclinal dips accompanied by arches and basins were observed. While normal faults were seen here and there in abundance, reversed fold-faults were less discernible. In northwest Hopeh and Jehol they appeared in great number. In Shantung, Liaotung and Jehol iron, copper, zinc and gold ores were found due to the presence of granite and the eruption of volcanic lava. To the west of this region the movement was less observable; it descended to form Kansu-Shensi basins where red beds (sandstone and shale) were found clustered together (fig. 4, III).

From the close of the Yen-shan orogeny to the beginning of the Tertiary, the earth's crust was gradually stabilized, erosion having caused the formation of many broad basins. These have been preserved on mountain tops in North China as historic remains. Simultaneously, gypsum, rock salts and loose red beds were deposited in the basins of Shansi, Honan, Shantung and Jehol, and coal fields were also formed at Fu-shun of Liaotung.

The Himalayan orogeny took place during the Eocene (Oligocene and early Cenozoic) forcing Liu-p'an shan of east Kansu to a tremendous height and basins west of Kansu to further depression. Red shale accumulated to a depth of 1,000 meters. The rise did not come until the beginning of the Quaternary. Basins in north Shensi started to rise in the beginning of the Eocene, mainly a time of erosion. In Shantung and Shansi the Himalayan Orogeny was principally of the meander and block-fault type,

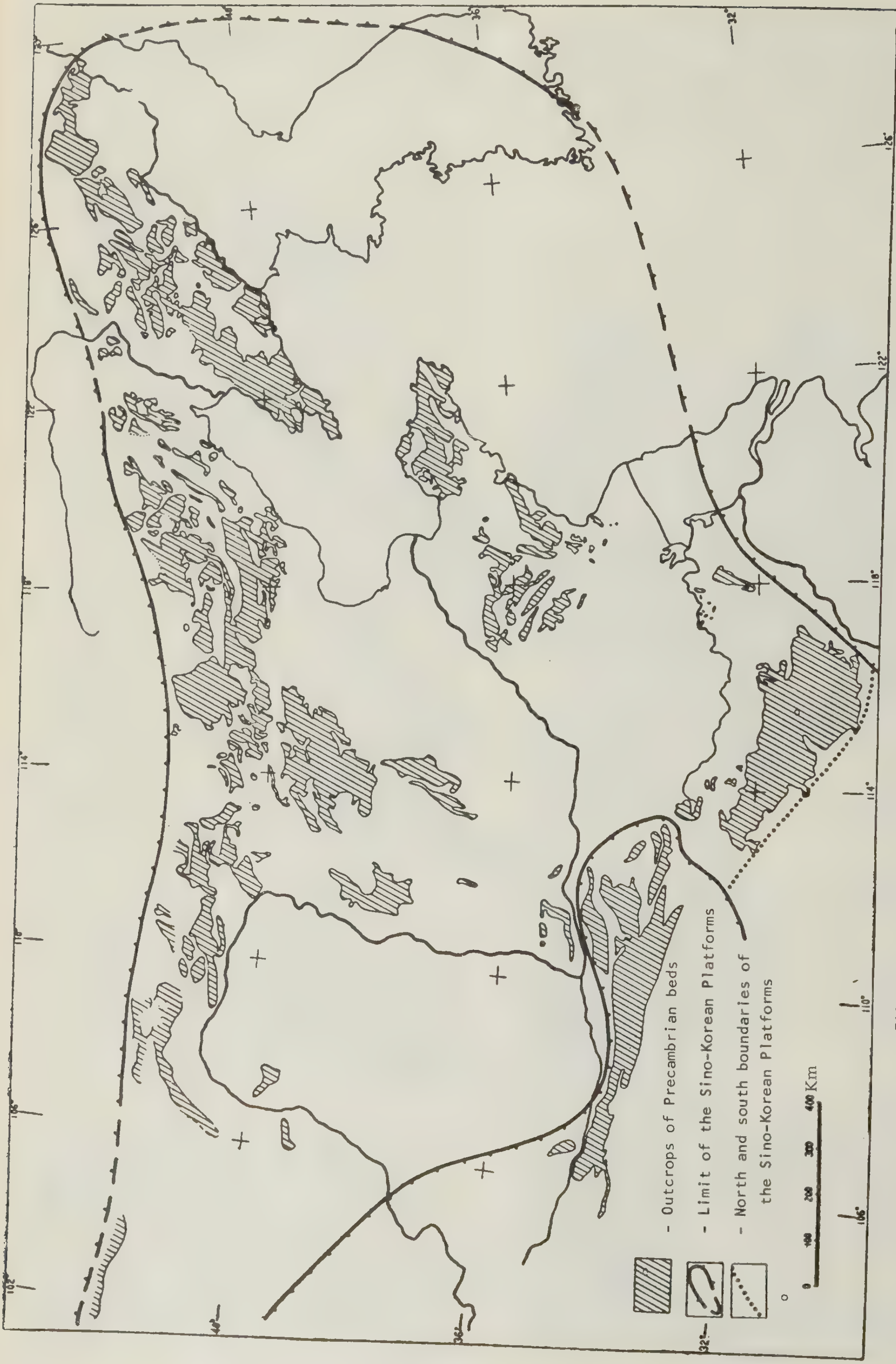

FIGURE 3. Sino-Korean Platforms and Distribution of Precambrian formations

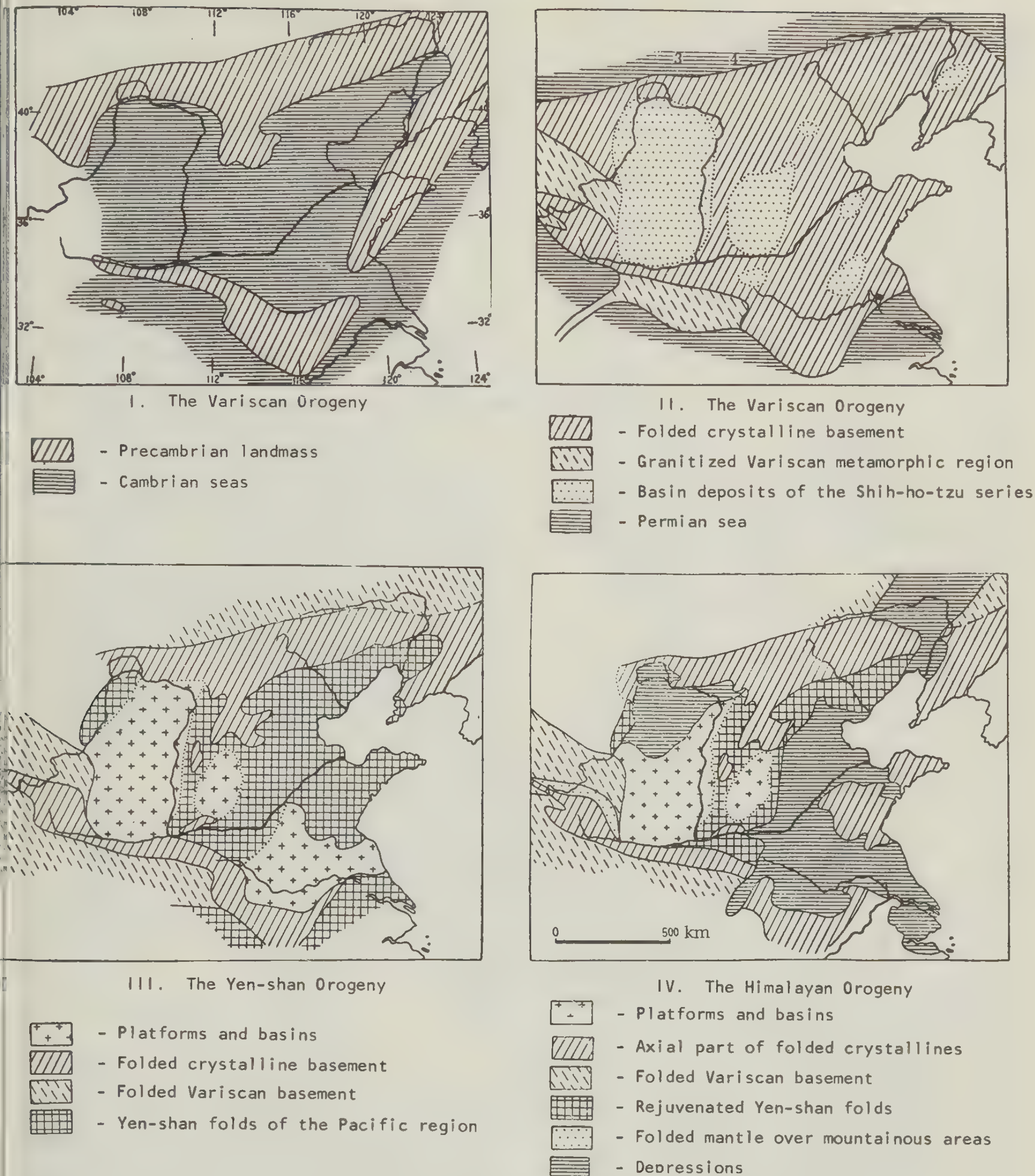

FIGURE 4. Paleogeographic maps of North China (based on HUANG Chi-ching)

the fault formation cited above being mostly the creation of this period. In Shantung, Jehol and north Hopeh flat-top ridges were formed because of the presence of basalt. After the Himalayan Orogeny the zone of depression extending from north Chinese plains through P'o Hai to the Liaotung plains became evident. Here was accumulated rock debris from the surrounding highlands (fig. 4, IV).

Broad valleys of the Tan-hsien stage were created as elevated erosional basin of the Himalayan Orogeny became denuded. In a broad belt, covering east Kansu, north Shensi, northwest Shansi, northwest Hopeh and north Jehol laterite (Paoteh stage deposits) was observed massed above the erosional basin. In central southeast Shansi sandstone and limestone lake facies were deposited. Consequently, the earth's crust had undergone further metamorphism, and erosion was revived causing Huang Ho, Fen Ho, Yung-ting Ho, etc., to fall abruptly. Thus, deep gorges (of the so-called Feng-ho stage) were formed. The Tan-hsien

stage features had been preserved in the upper sections of the gorges. Isolated gravel deposits (of the Sanmen stage) were found in the rapids along Huang Ho gorges [7]. At Huai-lai basin and in southeast Shansi fresh water earth [silt ?] fine sand and mud lake facies deposits were located (the delta deposits); in south Shansi, north Shensi, east Kansu and northwest Honan, extensive deposits of laterite were seen. The north plain was essentially an epicontinental sea and Shantung an isolated island during the "Peking Han" period (Pleistocene). Traces of glaciers now found at T'ai Shan, Lao Shan, T'ai-hsing Shan, Wu-t'ai and Lu-liang Shan were indicative of the cold climate then prevailing. Loess was extensively deposited in North China up until the Quaternary.

Sea level tended to rise continually, but waterways fed by Huang Ho silt deposits prevented the terrain from sinking and brought the vast plains into existence, basically consolidating present coastal features. Since history was written, the face of Nature has been changed by the activities of mankind.

The Three Great Geomorphic Regions

From west to east three distinct topographical belts may be marked out, mainly because this region lies between the Ch'ing and Yin Shan mountain ranges: the first belt comprises the loess plateaus of Hopeh and Jehol which rise to an average height of more than 1, 000 meters. Some mountains blanketed with loess (Liu-p'an Shan, Wu-t'ai Shan, Hsiao-wu-t'ai Shan, etc.) rise to a height of almost 3, 000 meters. The land features are complicated: west of this region the mountain ranges of Shansi of Kansu are shaped like "shan" [the Chinese character for mountain], with Chi-lien Shan running northwestward in the west and Lu-liang Shan northeastward in the east, bounded in the south by Ch'ing-ling which literally connects the two ranges to the north. Liu-p'an Shan which runs in a north-south direction is really the backbone dividing the plain into two broad basins in north Shensi and central Kansu. The basins so created have now become plateaus with their fringes coming in close contact with the main folds where fissures may be observed and earthquakes are frequent. Inside Shansi T'ai-hsing Shan, Ho Shan, Lu-liang Shan, etc., all running from north-northeast to south-southwest, constituted the anticline of the Yen-shan Orogeny, the center portion consisting of metamorphic shale of the Precambrian with the wings composed of calcareous shale of the Paleozoic. The broad inclined area between the ridges were filled with sandstone shale of the Secondary Era [Mesozoic-Cenozoic ?]. In central Shansi and close to the anticline were Fen Ho fault troughs. In the Hopeh-Jehol mountain regions folds from northeast to southwest were intercepted by folds from east to west. Here the earth's crust was dissected into narrow parallel fault blocks where granite and volcanic conglomerate were in evidence.

The second belt covers an area from North China's plains through P'o Hai to the Liao Ho plains. After the Yen-shan Orogeny the terrain began to decend, the lowlands in this region being mostly less than 50 meters above sea level. Alluvial deposits had been accumulated. At Tientsin and west Shantung, artesian wells may be drilled to a depth of 700 to 500 meters respectively before reaching bedrock.

The third belt covers Shantung and the east Liaotung rolling country which averages 500 meters above sea level, although individual mountain ridges may rise to 1,000 meters above sea level (T'si Shan 1,532 meters above sea level). Here the ancient metamorphic fault blocks, penetrated by granite during the Yen-shan Orogeny, formed domelike arches with faults in central Shantung. At Liaotung and Chiao-tung the ranges trend from northeast to southwest. This terrain, having been subjected to full-scale erosion, is predominantly characterized by domes [monadnocks ?].

These three topographical belts, may be subdivided into six broad areas. The first belt consists of loess plateaus and Hopeh-Jehol mountain ridges, the two being significantly different in type; the second and third belts are divided by P'o Hai into North China and Liao Ho plains and the Shantung rolling country is distinguished from Liaotung. The remaining belts may be seen in Figure 5.

Loess Plateaus

Loess plateaus cover Shansi (north Shansi excepted), north Shensi, Kansu (Ho-hsi corridor and south Kansu ridges excepted), and northwest Honan, bounded by T'ai-hsing Shan, Ch'ing-ling, Wu-ch'iao-ling and the Great Wall in the east, south, west and north at an average elevation of 1, 500 meters.

The distribution of loess and topography

Loess accumulation varies greatly in depth even within the same zone. Broad shallow basins on the plateaus (for example, in central and east Kansu, north Shensi and east Shansi) are carpeted with a layer of clay from several meters to more than a hundred meters, thinning out on the slopes of abrupt ridges. Existing records on the depth and thickness of clay cover indicates that loess tends to occur lower and thin out in a west-east direction. In central Kansu it is over 100 meters thick. However, Hua-chia-ling, 2, 400 meters above sea level, is also covered with loess. In the upper reaches of Ching Ho it is 100-150 meters deep; on the eastern slope of Liu-p'an Shan which is 1, 700 meters above sea level, there is also clay cover. In north Shensi it is less than 50 meters thick, distributed over an area under 1, 300 meters above sea level. On Shansi plateaus it is about 30 meters deep, and at the basins to

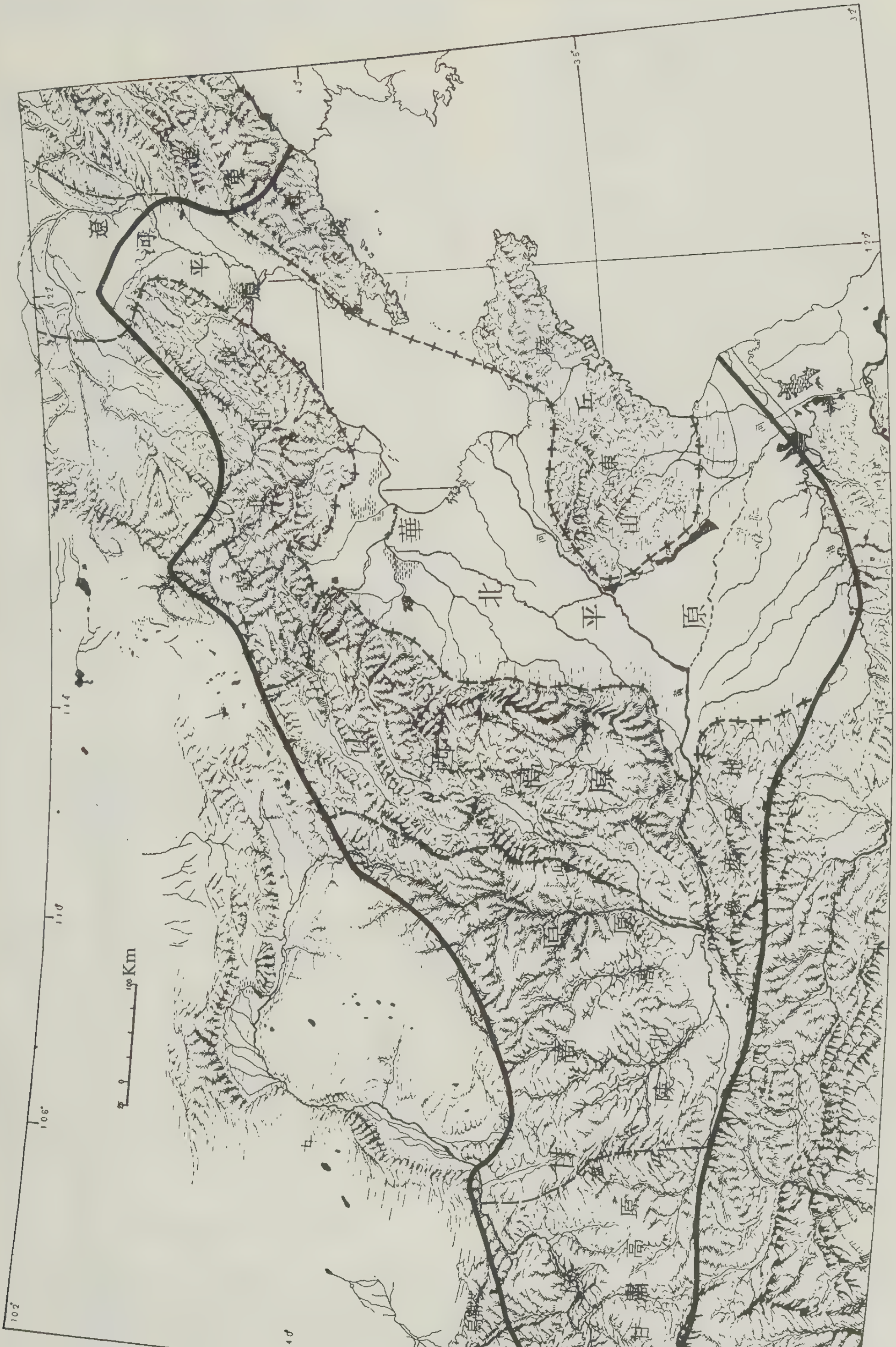

FIGURE 5. The geomorphologic regions of North China

— Geographic boundary ++++- Boundaries of the 3 major geomorphic regions ---- - Boundaries of the 6 geomorphic subregions

Drawn by CHOU T'ing-ju, SHIH Ya-feng, and CH'EN Shu-p'eng

the east in the direction of the Hopeh-Jehol mountain regions it is generally less than 20 meters. In respect to granular structure the sand content decreases and its adhesiveness increases as it moves from northwest toward southeast, according to an east Kansu and north Shensi analysis proving that its grain becomes finer farther away from the Mongolian desert[6].

Loess is generally loosely constituted and contains fine sand particles (0. 05 - 0. 002 mm) in diameter and clay (less than 0. 002 mm). It is passive to air currents mainly under Grade 4 and 5 wind action, it is miscible in water, and it is low in moisture-absorbing and wash-resisting power. Perpendicular bluffs are formed when brooks and ditches are washed by clay-saturated streams, contrasting distinctly with the flat plains lying among the valleys. Loess regions are marked by depression, underground currents, natural bridges and similar features, resembling somewhat corroded limestone shale [karst ?].

Vast amounts of loess was accumulated during the latter part of the Eocene. According to wind-abrasion theory, blasts of dust were blown over the plateaus from the Mongolian desert by violent northwest winds, and this wind action has continued. No noticeable change in contour and drainage system had occurred when clay began to accumulate, but in areas where its collection was accelerated and where river erosion had progressed at increased pace, the depressions were filled in and broad plains formed. In areas where this action was balanced or was superseded by the erosive forces of water, the domes and ridges were kept intact, and in some cases the contour became even more irregular.

Erosion by water was rather mild and slight when the terrain was covered with steppe or forest, and these natural protective coverings were severely damaged after thousands of years of planless and reckless cultivation and stock raising. Erosion became intensified.

Meanwhile, erosive forces are actively at work on the loess plateaus where streams and ditches are from 10 to 300 meters in depth, and their area is being rapidly extended. According to scanty records now available on north Shensi and east Kansu, they expand at the rate of 0. 3 meters per year. Avalanche and torrential flow are frequent, the ditch walls being perpendicular. The terrain lying between streams and ditches, exposed as they are to continuous erosion from precipitation, gradually lowers. In north Shensi where erosion is not rapid, the loss in clay is placed at 0. 5-1. 0 cm annually.

In respect to erosion, the clay contour may be examined according to three different categories: type one comprises slightly damaged and very flat platforms known as clay plains which may be as large as many kilometers in dimension, for example, Tung-chih-yuan on the upper course of Ch'ing-ho and Lo-ch'uan-yuan in the center of Lo-ho. Type two refers to clay domes and ridges which were formed after the plains had been dissected. In some cases they were domes and ridges before clay was deposited. Remaining long ridges between the streams are termed "liang" while isolated domes come to be known as "mao." A representative loess district in north Shensi is sometimes so intersected by streams and ditches that they are separated from one another by 200-300 meters, accounting for almost half of the area under study. The streams are more than 100 meters deep. Type three known as "ch'uan-ti" [stream-strewn terrain] deals with accumulated islands, flanked by alluvial fans, within a network of streams. Being exceptionally adapted to agriculture, these areas have been popularized as "mi-liang-ch'uan" [grain streams].

Valleys and mountain basins are also covered with loess. Being relative low, the terrain is less subject to erosive forces at work although erosion takes place at the lóess terraces along the banks of large streams. Basins in Shansi are marked by dome ridges and are poorly dissected.

Broad plateaus are subject to similar erosive influences but those of Shensi and Kansu west of Liang-shan and Liang-shan itself differ materially from those of Shansi along the T'ai-hsing Shan range. In general, eroded loess domes and ridges in Shensi and Kansu constitute an overwhelming majority while rock ridges towering above plateaus and basin plains buried among the plateaus are of secondary importance. Less than half of Shansi is covered by loess, whereas rock ridges, dissected plateaus and basin plains are so intersected that a degree of distributional balance is attained.

The Shensi-Kansu Plateau

The Shensi-Kansu plateau comprises the northern and central portions of Shensi and the eastern and central sections of Kansu. It is divided by the Liu-p'an-shan range, 3, 000 meters above sea level, running from south to north and bisecting the plateau about 2, 000 meters above sea level at the Kansu plateau in the West and below 1, 500 meters at the north

[6] Hsing-yi, Wen Ch'i-hsiao: How to Reconstruct Soil in the Northwest (Science Review, October, 1953), containing concrete figures on loess grain structure in North Shensi and East Kansu [10].

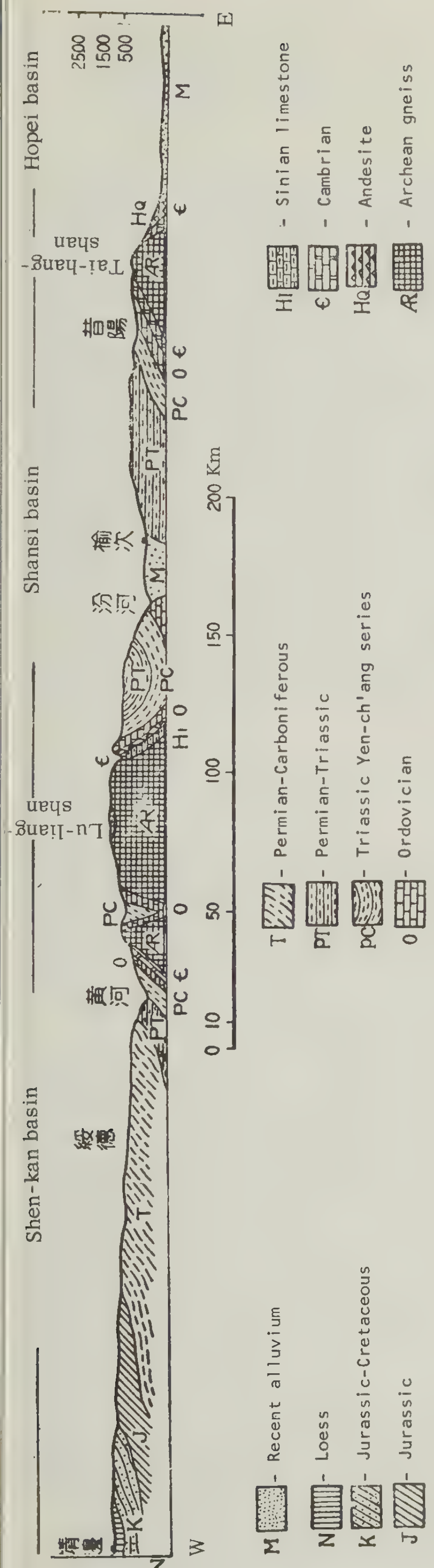

FIGURE 6. Geological cross-section of the Shensi-Kansu and Shansi Plateau (based on T. F. Hou's Geology of the Huang Ho Region)

Shensi plateau in the east.

Liu-p'an-shan composed of Cretaceous shale and psammite was newly created by the Himalayan Orogeny. In the center there is an outcrop of crystalline shale [schist ?]. The movement of earth's crust continues, accounting for the recurrence of violent earthquakes. On 26 December 1920 the famous Kansu earthquake had Li-p'an-shan for its epicenter. Earth tremors were violent. Because of avalanche of loess formations casualties exceeded a hundred thousand. In respect to geological structure, plateaus east and west of Liu-p'an-shan are basins superimposed over land mass depressions [graben?]. Under the loess are seen layers of red earth and shale deposits. Basins of north Shensi and Kansu rose up to form tablelands during the Tertiary and Quaternary respectively (fig. 6) [11]. Terraces were formed as drainage was deepened in the valley. For example, four distinct types of terraced land were found along the banks of Huang Ho at Lan-chou Ching-yuan and Chung-wei to the northwest of this region, the highest terraced land rising up to 200 meters above water level. Between Shansi and Shensi Huang Ho penetrated vertically into the fault-plains of the Mesozoic, the entire terrain assuming a majestic spectacle of cliffs, 20-300 meters high and 40-300 meters wide, increasing in number as the river turned from north to south. From Ho-chu to T'ung-kuan its height above sea level dropped from 800 to 300 meters. Here are found rapids and cascades of which the Wu-k'ou waterfall is the most impressive.

At T'ung-kuan, Huang Ho forms a perpendicular with Wei Ho. Along the banks of Wei Ho below Pao-chi are seen narrow strips of plain 280 kilometers long from east to west and 60 kilometers wide from south to north. These plains were developed from partially formed Tertiary red shale. During the Himalayan Orogeny, faults were formed along its banks in the shape of graben covered with loess deposits, causing the river to ascend still further. The banks of Wei Hao are now marked by alluvial plains only 5-30 kilometers wide. A class 2 land terrace known as "T'ou-tao-yuan" [first line plain] and "Erh-tao-yuan" [second-line plain] is preserved in good condition on the north bank. At these fault-troughs violent tremors had occurred in 1956.

T'iao Ho, Lo Ho and Ching Ho (other tributaries of Huang Ho) all cut deeply into the plateaus. When they penetrated the shale layer beneath, deep yellow and red clay gorges were formed. Where the shale layer was easily penetrable, broad river plains (such as the Lin-t'iao plain, 5-8 kilometers wide) were formed on T'iao Ho.

Emerging from the drainage area are numer-

erous river valleys which help carve the clay-covered plains into isolated lots. On the upper reaches of Ching-ho in east Kansu are kept intact plains of this type (about 8. 2 percent). Ma-lien-ho, a tributary of Ching-ho, and T'ung-chih-yuan of P'u-ho, 60 kilometers long from south to north and 20 kilometers wide from east to west, now figure prominently as grain producing centers in east Kansu. "Liang," "Mao" and 70-80 percent of their slopes lie above the valley at a height of 300-350 meters. The area watered by the affluents of Wu-ting and Ching-chien in north Shensi branched into a network of streamlets. Measurements made at Chiu-yuan-kou, Sui-te, indicated that there were 3. 5 kilometers of river valley per square kilometer with 70 percent of its slope at 26^{o} and less than 4 percent at 15^{o}, the depth being 50-100 meters. Evidently the terrain was rather thoroughly disorganized. At Hua-chia-ling, T'ien-shui, in south Kansu an intermediate model was found - an alternation of troughs and peaks. Domes and ridges buttressed by round-top slopes and wavy valleys were seen in great number. Farms were laid out in layers and terraces, known as "Lung-p'o" [Kansu terrace] along the mountain slopes. On the border of Shensi and Autonomous Mongolia were developed weathering sand formations traversing a distance of 600 meters from Fu-ku through Yu-lin to Ting-pien along the Great Wall. Vast lakes over sandy plains had dried up, revealing their under structure. The sand bar was placed under cultivation. Crescent-shaped sand dunes [barchans], 7-20 meters high with a distance of 30-100 meters from peak to peak, were formed when sand particles were disturbed and conveyed by violent northwest winds. These sand dunes moved continually southward at the rate of about 3 meters per annum. Sandstorms reached Sui-te, ruining agriculture and forcing people to flee. Their livelihood in the north Shensi borderland was greatly threatened. After the establishment of the Chinese People's Republic a forest zone was laid out in the north Shensi border region as an anti-sandstorm measure. It was planned that this zone would consist of a trunk belt, 512 kilometers long, supported by eight strips of 452 kilometers each [12].

The Shansi Plateau (northeastern mountains in Honan are included)

The Shansi plateau is flanked by T'ai-hsing Shan in the east and Liu-liang Shan in the west. In the north, Heng Shan meets the mountain ranges of Hopeh and Jehol. Its southern boundary is separated by Huang Ho valley and mountains in west Honan. Loess-covered plateaus are superseded by a convolution of mountain ranges stretching from west to east. Basins and plains in their midst are small in dimension. T'ai-yuan and Lin-feng basins along the Fen-Ho fault trough and Ch'ang-chih in southeast Shansi may be cited as examples different from the Shensi-Kansu Plateau (fig. 6).

The Fen Ho fault trough belt divides the Shansi Plateau into three parts: west Shansi (mountains and highlands), central Shansi (fault trough basins), and east Shansi (plateaus and mountain regions).

West Shansi is characterized by Lu-liang Shan which links with Yu-men-shan in the southwest with Huang Ho between them, extending northeastward to Lu-yan-shan and lying mainly to the north of Li Shan, Feng-yang. Its width and altitude have apparently increased; it contains a peak 2, 800 meters high (Kuan-ti Shan at 2, 791 meters) composed of firm, hard and fine-grained calcareous shale and quartzite of Cambrian, Ordovician, and Sinian ages, respectively. The peak rises precipitously over this area. On both sides of Lu-lian Shan are located broad slopes resembling plateaus. At Pei shen-ch'ih and Wu-s'ai in northwest Shansi are found broad valleys and isolated hills where drainage has slowed down. The terrain is of the early medium mature type. In structure the east slope of Lu-liang Shan and Fen Ho valley are dotted with broad loess-covered inclines. The southern part near Fen-yang is so eroded that the plateau surface becomes almost unrecognizable; the northern part near Ching-lo is less marked by streams and valleys. Here, the plateau features seem to be more revealing.

The fault trough zone in central Shansi is formed by three major faults - one belt extending from I-chou southeastward toward Chiao-ch'eng in the northwest and the other from T'ai-ku southeastward to Lin-fen in the northwest. In the northeastern part these two fault belts are inclined to the southeast of the fault-line; in the southwestern part they lie to the northwest of the fault-line. The third fault extends from the west of Ho-shan to the north of Chung-t'iao Shan. These three faults account for the formation of I-chou (1, 000 meters above sea level), T'ai-yuan (700 meters above sea level), Lin-feng and Yun-ch'eng (over 300 meters) basins. The I-chou basin was filled in with loess; the terrain is flat, stretching northward to Fan-chin and T'ai- hsien. Its streams empty into Fen Ho and meander through the west slope of T'ai-hsing Shan where Hu-t'o-ho runs in an easterly direction. The T'ai-yuan basin is the largest alluvial plain in Shansi, 50 kilometers wide and 150 kilometers long. In the south of T'ai-yuan where drainage had been blocked, lakes have appeared. Along the upper reaches of Fen Ho the Lin-feng basin broadens out at Ho-chu, 20-25 kilometers wide and 150 kilometers long, with broad loess platforms at its edge. Flooded plains are seen along the river. The basin cuts through Huang Ho valley where it merges with the Wei-ho plain. The Yun-ch'eng basin lies low, and because of poor drainage a lake group has been formed. Salines well-known in Shansi are found in the southern part of this basin.

Topographical features in east Shansi are rather complicated. Fault-inclines lying between Ho-shan and T'ai-hsing Shan are covered with thick layers of loess. They lie at an altitude of 1, 500-2, 000 meters, rising to over 2, 000 meters at the upper course of Chang-shui. The plateau is literally hemmed in by Fen Ho, Ch'in Ho, Chang-shui and Hu-t'o Ho and their tributaries, causing deep river valleys to be formed. On top of the Plateau are located many basins of which the most important is the Chang-chih basin, 30 kilometers long from east to west and 20 kilometers wide from south to north. It rises to an altitude of 1, 000 meters above sea level. The basin surface is marked by a convolution of loess mounds and sluggish streams. There are other basins such as Hsiang-yuan, Ch'in-hsien, Shou-yang, etc. The plateau is encircled by mountain ridges with moderately inclined slopes and a number of faults in the rear where the slopes vary greatly in steepness. To the west of the plateau lie Ho Shan and I-chou Shan (northeast of T'ai-yuan). Ho Shan rises to nearly 2, 600 meters and has flat crests, possibly of limestone. In east Hopeh the ridge is inclined by single rows whereas in west Hopeh it is characterized by faults dropping abruptly toward the Fen Ho valley. To the north was Wu-t'ai Shan and Heng Shan. Wu-t'ai-shan is the highest peak in Shansi, rising to almost 3, 000 meters with slopes above 1, 800 meters gradually flattening out. On top of the peaks are many flat platforms - representative erosional feature in North China. On its southern and southeastern slopes is evidence of small-scale Pleistocene glaciation [13]. Heng-shan is one of the famous peaks in China, 2, 000 meters high. Its principal crest is composed of limestone [and ?] shale; its southern slopes are slightly inclined with steep northern slopes running into the Sang-kan-ho valley. To the east of the plateau lies T'ai-hing Shan, less than 1, 000 meters above sea level, being lower than the mountains cited above. But its faults and cliffs, over 1, 000 meters high, tower over the North China plain. Many valleys had been formed as streams meandered through the Shansi plateau after crossing the east slope of T'ai-hsing Shan. It now serves as the principal gateway to the Shansi plateau. Liang-tse-kuan, through which the Cheng-Tai Railway runs, is the most famous pass in this area. The southern end of T'ai-hsing Shan turns westward along the Chung-t'iao-shan range where its principal peak rises to an altitude of nearly 1, 900 meters. The faults at its northern incline fall abruptly into Huang-ho valley, forming alluvial fans.

The course of Huang-ho is impeded at T'ung-kuan between Shansi and Shensi by Hua-shan which runs from east to west. As it turns eastward its valleys broaden out.

A clay-gravel terraced terrain is seen along the river bank but Huang-ho turns into a gorge east of Shen-hsien. The famous San-men gorge with its two tiny islands (known in Chinese history as "bulwarks in the rapids") is composed of porphyry. The rolling country tranversed by Huang-ho at Yuan-ch'u near Hsin-an suddenly opens up into a broad valley and links with the North China plain.

South of Huang-ho, west Honan mountain ranges which cover Fu-niu-shan and Hsiung-erh-shan (2, 256 meters) and Sung-shan (1, 368 meters) extend from northeast to southwest where they come in contact with Ching-ling The peaks consist of Precambrian metamorphic shale with a sprinkling of granite and An-shan shale. They run through small plains and gorges alternately along the I-ho and Lo-ho valleys. The Lung-hai Railway passes through I-ch'uan and I-yang, a broad belt covered with loess which at one time probably were loess plateaus.

The North Hopeh Mountain Terrain

The North Hopeh mountain terrain extends from Heng-shan in north Shansi through I-wu-lu-shan west of Liao-ho, about 1, 000 meters above sea level, with a group of domes and faults stretching from east northeast to west southwest forming parallel crests and plains. This region lies between the Mongolian plateau and the coastal plains, gradually inclining southward from the north. In the northern part erosive influences are less noticeable and the terrain is flat. In the south the land surface is badly dissected, indicating that erosion had been violent.

While topographical features in north Hopeh are more or less comparable they are, however, typified by independent drainage systems. Mountain valleys in north Hopeh are simple and are prominently marked but they are complicated and disorganized in Jehol.

The Nan-k'ou range in the southern extremity of north Hopeh functions as an axle for near-by folds; its toothshaped ridges are composites of sandstone, limestone and quartzite. Hsiao-wu-t'ai-shan (southeast of Wei-hsien), the highest peak of the loftiest mountain ranges in North China, is 3, 491 meters above sea level. It is composed principally of quartz porphyry with huge faults on the northern slope descending toward the basin of Wei-hsien. Western Hill in the neighborhood of Peiping runs parallel to the Nan-k'ou range, generally 500-800 meters above sea level. Chao-chieh and Hiao-feng peaks exceed 1, 300 meters in height and are located on the fault-incline. The crests are composed of spotted gravel shale with somewhat inverted features [?].

Small domelike ridges lie to the north of the Nan-k'ou range, a chain of basins on the upper reaches of Yung-ting-ho being the most out-

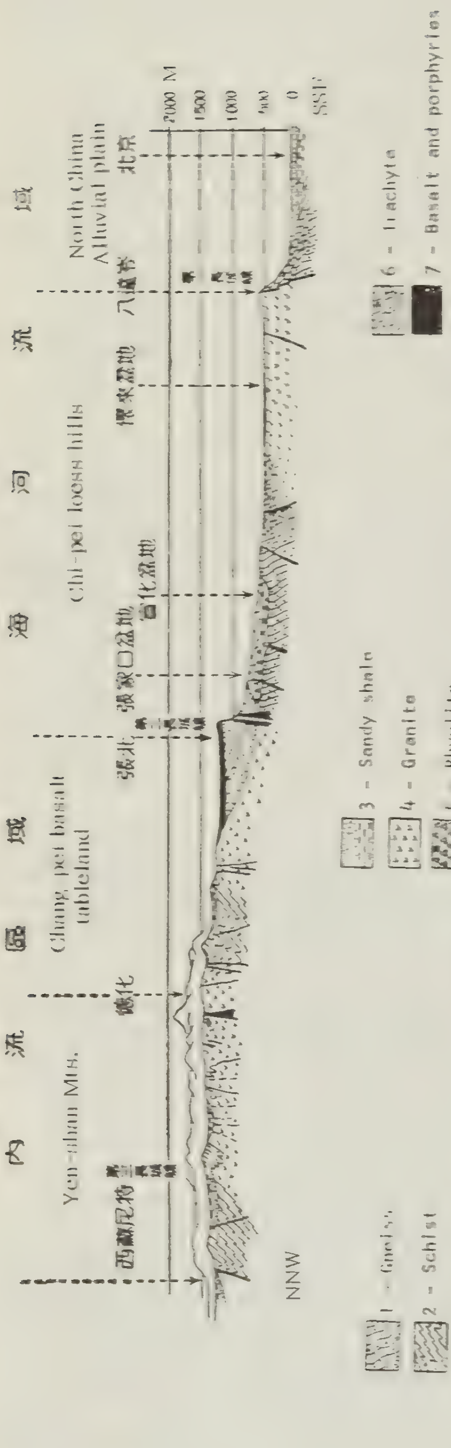

FIGURE 7. Cross-section of geological features in North Hopei
(based on material from a Japanese publication: Geological Aspects of North China and Mongolia)

standing. Of these basins the largest are the ones at Huai-lai and the Ta-tung basin on the upper course of Sang-kan-ho. The Huai-lai basin is 30 kilometers wide, 120 meters long and 500 meters above sea level; it is filled with volcanic ash, fine sand, lake deposits, and loess. The terrain is flat and its drainage is meandrous. To utilize such features, public dams have been constructed at the entrance of Yung-ting-ho through the mountain ranges [14].

The Ta-tung basin, 30 kilometers wide and 150 kilometers long, is marked by loess mound folds. To the northeast lies a cluster of extinct Quaternary volcanos.

The northern part of the North Hopeh mountain region terminates in the vicinity of Kalgan in rows of mounds and ridges over 1,000 meters above sea level, corresponding to the Mongolian plateau in the north. Mounds, ridges and plateaus are composed of basalt. Originally they formed a composite whole, the mounds and ridges being parts of a southern extension of the Mongolian plateau. The rolling country was subsequently dissected by streams and its height reduced to approximately 300 meters (fig. 7).

This region consisting of long narrow strips of land mass runs from northwest to southwest. Here two groups of faults are noted: one extending northeast-southwest and the other running northwest-southeast, these intercept each other but the former is more densely constituted than the latter.

This region is divided into three belts by the faults from northeast to southwest: the Sung-ling range, the ridges near Chien-p'ien and the Ho-yuan upland.

The Sung-ling range lies to the west of Liao-ning, about 300-400 meters above sea level though some sandstone peaks rise more than 800 meters above sea level. Because of its proximity to P'o-hai, the area has been subjected to heavy stream erosion. Deep valleys, canyons and cliffs have been formed. I-wu-lu-shan, a solitary elevation, lies between the Fou-hsin and I-hsien mountain regions and the Liao-ho plains.

The Chien-p'ien ranges, about 1,100 meters above sea level, are located to the north of the Sung-ling range; they were formed by volcanic lava and sandy limestone shale, the lower part being formed with pitted surface fault [?] while some broad slopes were covered with loess and red earth. They serve as a dividing line between Ta-ling-ho and Lao-ha-ho (a main tributary of upper Hsiao-liao-ho). South of Ta-ling-ho the land mass is dissected while terrain north of Lao-ha-ho is comparatively flat.

In the northwestern part of upper Lao-ha-ho, the terrain rises to 1,450 meters in altitude at

Tsui-tsu-shan Peak near Wei-ch'ang. It is principally composed of granite with An-shan [gneiss ?] and liparite.

Sai-hsing-pa and I-k'en-pa which lie to the northwest of Wei-ch'ang Feng-t'ing respectively, about 1, 700 meters above sea level, form the boundaries of the Mongolian plateau. They were composed of basalt and liparite. Sai-hsing-pa and I-k'en-pa function as a line of demarcation between the Jehol mountain range and the Mongolian plateau.

Mao-hsing-pa, Ma-an-shan, etc., about 1, 000-1, 500 meters above sea level, may be mentioned as important ranges that extend from the south of Wei-ch'ang through Lung-hua, Ning-ch'eng and K'ou-la-ch'in-ch'i to P'ing-ch'uan. These ranges all run from northwest to southwest.

On the upper reaches of Luan-ho and Ch'ao-pai-ho, running from northwest to southeast (in a somewhat east to west direction), the ranges ramify over a broad area. Steep valleys, canyons and rapids are formed at Luan-ho and Ch'ao-pai-ho which cut through this region. As Luan-ho penetrates into the Mongolian plateau it cuts through the borderline of the plateau, passing through Ch'eng-te basin which was filled with volcanic lavas. Here the river is flanked by alluvial plains and loess platforms. At its lower reaches Luan-ho crosses the Great Wall from Hsi-feng-k'ou into the North China plains.

Inasmuch as these ranges come into contact with the Yen-shan range at their southern extremities, the former merges with the latter which runs from east to west. Being parallel to the Great Wall, this region is sometimes known as the Great Wall Range. It is linked to the Nan-k'ou range in the west and the Sung-ling range in the east; it rises to 1, 000 meters in height and is mainly composed of densely-formed sandy limestone and granite. Wu-ling-shan (2, 100 meters above sea level) and Tu-shan (1, 670 meters above sea level) rise to a great height. Its southern slope is dotted with domes and ridges extending to the neighborhood of the Chin-Shan Railway [16].

The Shantung and Liao-tung Rolling Country

The Shantung and Liao-tung rolling country rises from the southeast of the North China and Liao-ho plains, generally less than 500 meters above sea level, with the exception of a few peaks that rise more than 1, 000 meters above sea level. Slopes and valleys are broad, and the terrain has attained maturity.

Opposite each other, the peninsulas rise from the sea; their stony shores are marked by promontories and indented bays of the Lias type. Islands are linked to the land mass by sand bars which seem to have been formed rather recently. On the slopes layers of wave-cut terraces are noticeable.

In the west the Shantung rolling country borders on the North China plain with P'ou-hai and Huang-ho in the east; it is divided at the center by the Chiao-Lai plains of erosion into the central Shantung mountain region and Chiao-tung Peninsula. The central Shantung region is arch-shaped with T'ai-shan and I-shan, 400-1, 000 meters above sea level, running from east to west. The T'ai-Shan peak which is flat-topped rises to a height of 1, 532 meters above sea level at the west extremity of this region. Tsu-lai-shan and Meng-shan run parallel to each other in a northwesterly direction and are linked with T'ai Shan like a pair of scissors. In the western part, the southern slope of T'ai Shan merges with the Ta-fen Ho faults which are littered with loess platforms. Small-scale alluvial plains are discernible along the banks of Ta-fen Ho.

North of the T'ai-I ranges steep limestone strata are alternately intercepted by sheet rocks, forming rows of tooth-like mounds among which may be seen many basins and low-lying domes in loose soft strata. Su-p'o is a good illustration. West of the slope are found slightly dissected loess platforms (fig. 8).

The rolling country on the upper reaches of I-chiang in South Shantung is covered with thick layers of limestone. Its topography is marked by square-shaped hillocks, popularly called "ku" (Tung-han-ku, Meng-han-ku, etc.). Here broad basins and inverted boat-shaped domes indicate its proximity to the erosional plains of North China.

Streams radiating from this region are loaded with weathering materials, causing alluvial fans to be formed as Ta-fen-ho, I-chiang and Ssu-shui meander through the ranges. Floods frequently occur on the lower reaches of I-chiang where the stream is hopelessly blocked. After the Liberation, Ma-ling Shan (formed of low pitted shale [?]) was tunneled to permit I-chiang to lead into Sha-ho, and the drainage system was then reconstructed. Reservoirs were built at the upper reaches to prevent flooding.

The Chiao tung Peninsula east of the Chiao-lai plains is mainly composed of domes and ridges below 200 meters in height. These elevations were formed with erosion-resisting porphry and pegmatite. In addition there are two parallel ridges running from northeast to southwest (such as Ai Shan, K'un-lun Shan and Lao Shan) at an altitude of 600 meters above sea level, formed of granite and syenite. These mountains are elliptical in shape. Being encircled by low-lying domes, they seem to tower

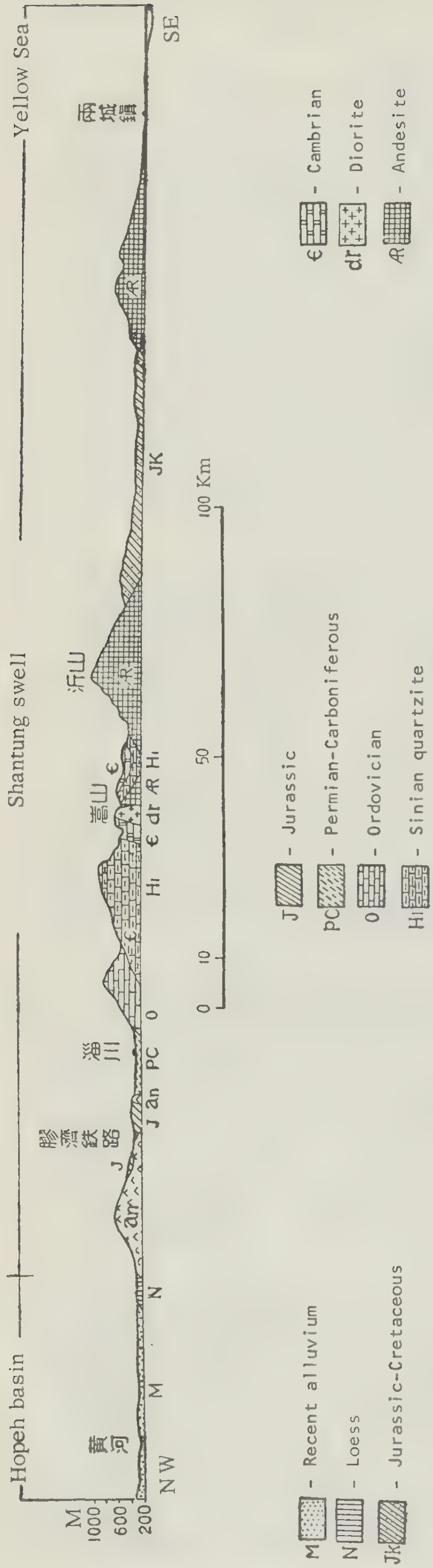

FIGURE 8. Geological cross-section of the Shantung Hills

above all crests in this mountain region. Because of the exertion of damp climatic influence on the mountains, spectacular rock columns and sharp ridges may be observed in this granite-covered region.

The coast-line is extremely indented; Ch'ang-tao, We-hai-wei and Yen-t'ai harbors are located along the coast. Chang-shan archipelago covered with basalt and located in Miao-tao Strait clearly indicates that depressions had existed between Shantung and Liao-tung. Promontories along the coast had been eroded by sea waves and alluvial beds had accumulated in the bays forming crescent-shaped plains of various dimensions. In the neighborhood of Yen-t'ai a chain of islands is linked to the mainland at Yen-t'ai, and stone platforms, 70 meters above sea level at their highest, are seen along the coast, proving that the terrain had ascended slightly after the depression period [17].

Liao-tung ridges with Ch'ien Shan as their backbone form the southern extensions of Tung-man Shan running from northeast to southwest, and faults had been formed in the same direction.

Mo-t'ien-ling, 560 meters above sea level, lies to the south of T'ai-tzu-ho. As it extends southwestward it comes in contact with the Chien Shan ranges. Here it divides into two ranges: the east ridge is about 900 meters above sea level and runs directly southward, being only once intercepted by Sha-lo between P'u-lan-tien and P'i-tzu-wo; the west ridge turns southwestward and terminates at Lao-t'ieh-shan (820 meters above sea level) in the vicinity of Port Arthur. The west ridge is comparatively narrow and small but it consists of sharp steep peaks more than 1,000 meters in altitude, flanked by domes of less than 400 meters in height, which form a great portion of the land surface of the peninsula. Lying between the domes and the coast are terraced landforms about 15 meters above sea level. These terraces were developed from pitted surface shale and faults of the Sinian period. Solitary rocks of hard granite and quartzose rock are seen projecting from the sea in the form of cliffs and sharp precipices. Here marks of erosion by sea water are not clear-cut, indicating that the terraces had been formed as a result of the recent rise in coastline. At Hsiung-yo on the west coast of the northern section of the peninsula the shoreline is simple; it is marked by sand dunes. On the southern section south of Fu-chou, a coastline of a Lias type had been developed. Streams and "Ya-tang", [possibly Adam?] bays east of Ch'ang-tao turn into rather weak river valleys. Chin-chou-wan and Ta-lien-wan were depressed basins before the rise. Port Arthur and Ta-lien are important Chinese harbors.

The North China and Liao Ho Plains

The North China and Liao Ho plains compared

with the landforms mentioned above possess characteristics distinctly their own. So far we have dealt with the rise of terrain in relation to the progression of erosion. Here we refer to land depressions involving principally the formation of alluvial deposits. The land surface is less than 100 meters in altitude, of which 90 percent falls below 50 meters (fig. 9).

The North China plain, being the largest in China, covers an area of 300, 000 square kilometers, bordering on the sea in the east and encircling the mountain regions in Shantung, with the Huai Ho plains in the south extending to the northern slope of Ta-pieh Shan; it is marked off from the loess plateaus by Fou-niu Shan and T'ai-hsing Shan in the West; in the north it is

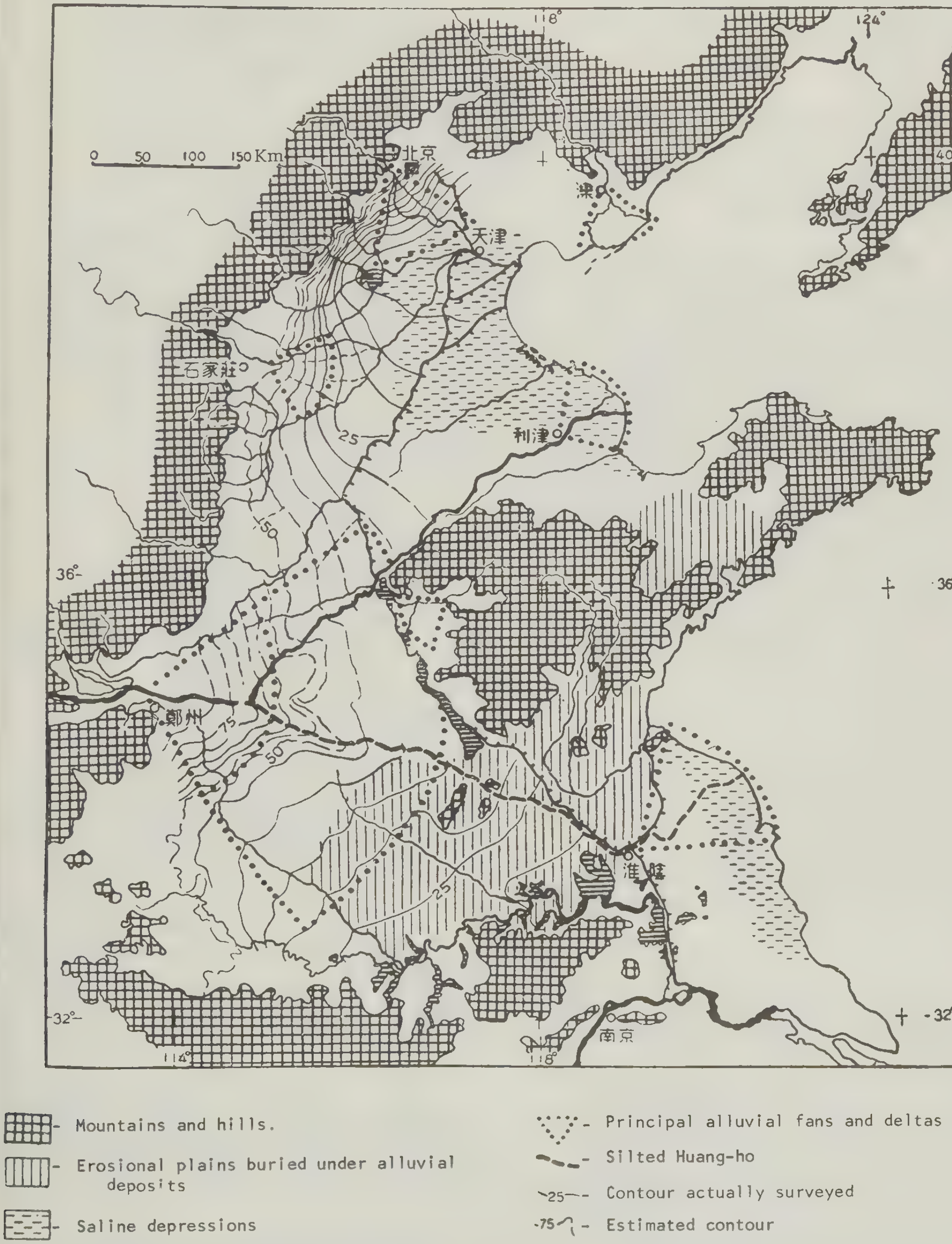

FIGURE 9. The North China Plain

connected with or close to the mountain regions of Hopeh and Jehol [18]; in the northeast it comes in contact with a land corridor leading to the Liao Ho plain between Yen Shan and P'o Hai.

Silt washed down by the streams in the west are mainly accumulated on the plain, which not only arrests its tendency toward depression but also causes P'o Hai to shrink in size. Fan-shaped landforms rise as the streams emerge from the mountains. Thus, natural dams are created on the plains and broad deltas are formed on the coast.

The river beds rise continually as silt is deposited on the plain. Following the construction of embankments, silting only becomes more intensified, and a "water ridge" is developed on the great plain [19].

About 400 million tons of silt is deposited annually in the area where Huang Ho flows between Shen-hsien of Honan and Luan-k'ou of Shantung, causing its turbulent stream to overflow its banks and its river bed to rise from 1.5 to 8 fen-mi [centimeters?] per annum. Such rises, though less marked, are also recorded at Yung-ting Ho, Luan Ho and Hu-t'o Ho. After passing through the San-men gorge, Huang Ho broadens out into a fan-shaped plain as it turns eastward from Meng-ching. The river bed between Meng-ching and Lan-feng rests on the ridge axle of this fan-like plain, which runs northward toward the Hopeh plain and southward toward the Huai-pei plain at a marked incline. Here lies the source for repeated inundations and alteration of the river course. The scope of this flooded area extends from Tientsin in the north to Huai-yin in the south (fig. 10).

The fan-shaped land surface of Huang Ho opposite the Shantung rolling country is markedly depressed at the center, is constantly threatened by floods in the west, and is connected with the Shantung mountains and streams in the east. Hemmed in by Huang Ho embankments in the north and blocked by silt accumulated in the south, shallow lakes such as Tung-p'ing, Cho-shan, Wei-shan, etc., have been formed in west Shantung.

The Huai-pei plain is four-sided; it extends along the southern slope of the alluvial fan in the direction of the northern slope of Huai-yang shan embracing from east to west the Ku Ho and Ying Ho valleys, the drop in incline being rated at 1:6,000 from northwest to southeast [20]. The four great affluents - Ying Ho, Fei Ho, Ku Ho and Kuei Ho flow into Huai Ho along the northern incline in a straight line. Because of frequent flooding it is difficult to distinguish the old river valleys from the new. Ordinarily, during the rainy season the area is flooded, a part of this flood water being ground water seeping through the river embankments.

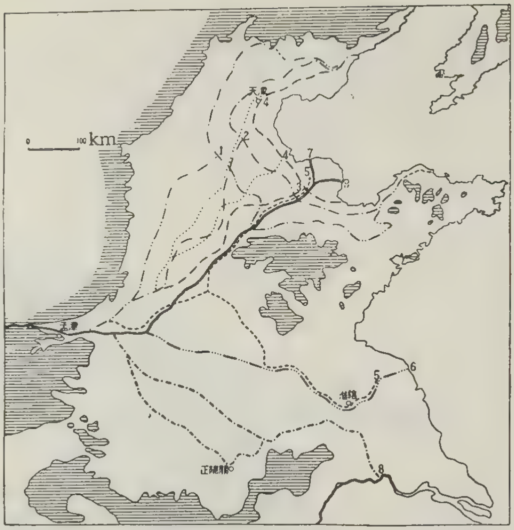

FIGURE 10. The shifting of Huang Ho's Course and the changing Coast (based on TAN Chi-hsiang's book : Historically Chartered Courses of Huang-ho and TING Su's book: Origin of the North China Plain).

1 -	Yu-ho's Original Course
2 -	602 BC to 10 AD
3 -	11 AD to 1047
4 -	1048 - 1193
5 -	1194 - 1493
6 -	1494 - 1854
7 -	1855 - 1937
8 -	1938 - 1945
7.9	9 -	1946 - 1958.

Tr: On the whole, Hai Ho and Huai Ho plains may be considered collectively as a delta of Huang Ho.

In 1938 the dikes were demolished by the reactionary Kuomintang government to keep a vast region south of Huang Ho flooded. For nine years vast areas in east Honan and north Anhwei were turned into scenes of successive disaster. In flooded areas accumulations of silt were four meters deep, and coarse sand was deposited in the channel. The sand particles became finer and finer farther from the channel. In remote regions the grains turned into a kind of sand-clay. The fertility of the alluvial plains was greatly increased. Over 50,000 mou [hectares?] of land turned bad because they were submerged completely in coarse sand. Since the Liberation this flooded region has been rehabilitated [21] (fig. 11)

Running from west to east Huai Ho dissects Pa-kung Shan, Ching Shan and Tu Shan into solitary mounds, forming a number of small gorges. On its banks are seen vast tracts of sandy alluvium or swamps.

East of Ku Ho isolated domes composed of Sinian limestone are found scattered along the Tientsin--P'u-k'ou Railway. These elliptically

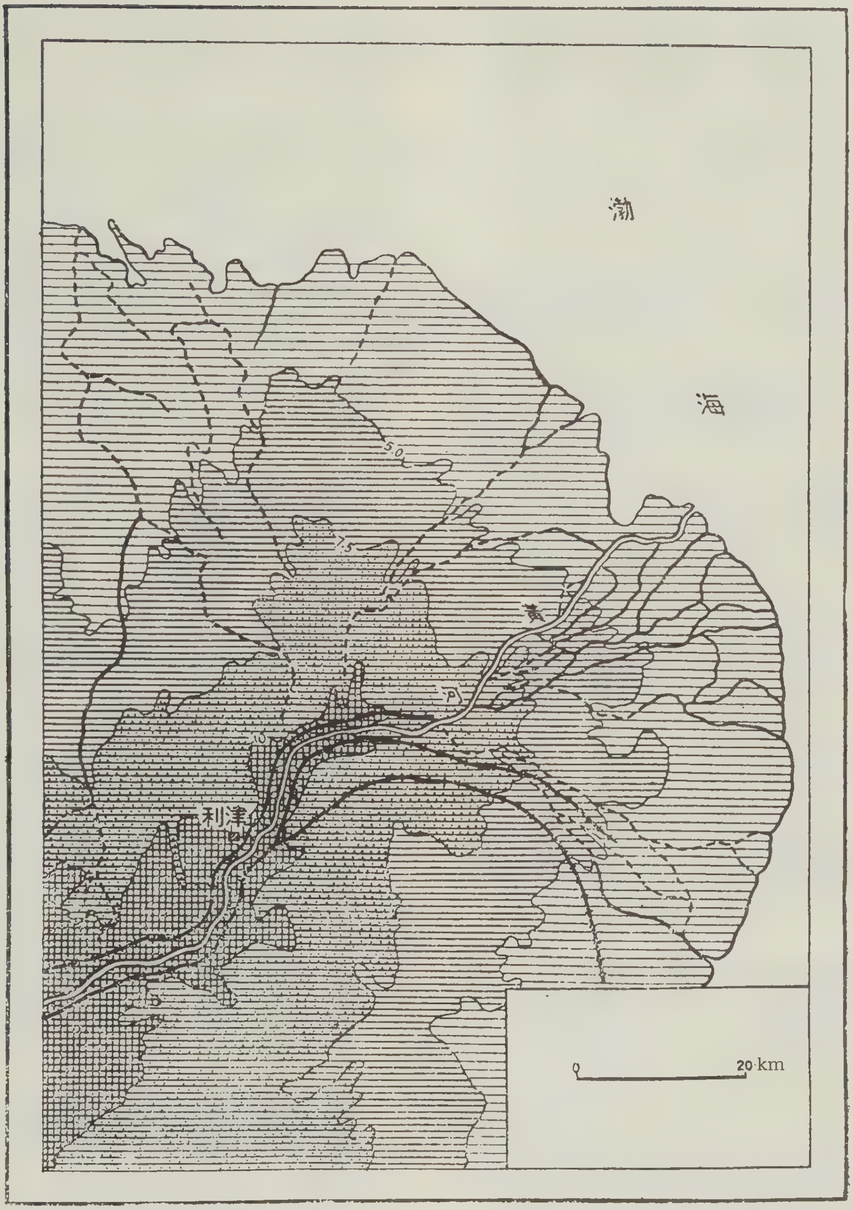

FIGURE 11. Huang Ho Delta (based on studies compiled by the Department of Geography. Topographical Map: 1:200,000).

1 - The river and dry river bed

2 - Dikes: 5.0 altitude [in meters?] above sea level

shaped domes are remnants of the eroded plain. Thick layers of alluvium are seen in the neighborhood, growing thicker toward the south until they merge into a broad plain between Su-hsien and Pang-fou.

Fan-shaped landforms, measuring from several kilometers to 40-50 kilometers in width, are found to the north of Huang Ho as it flows along the slopes of Ta-pieh Shan and Yen Shan. Large landforms were created by Chang-shui, Hu t'o Ho and Yung-ting Ho as they tumbled down from the loess plateaus. The inclines are steep and sharp, and the streams (of the radiating type) develop into two major alluvial fans with a network of streamlets and brooks. In some areas lakes are formed. By utilizing surface features and subterranean water, irrigation

schemes were developed in China two thousand years ago. Sand dunes are sometimes formed along the river banks as sand dust is blown up in winter from the dried river beds. These desert regions along the banks of Yung-ting-ho and Huang-ho are being rehabilitated by the adoption of a reforestation program.

East of the T'ai-hsing Shan alluvial fan and west of Huang Ho Delta as far as the coast of P'o Hai, special low and wet depressions known as the Hai Ho plains are interlaced with lakes and swamps. Lagoons such as Ch'i-li-Hai, Pai-yang-ting and Wen-an-wa are located in the vicinity of Tientsin and areas to the west. Flowing from the upper reaches of Hai Ho are five main streams (Nan-yun Ho, Tzu-ya Ho, Ta-ching Ho, Yung-ting Ho and Pai-yun Ho), which are clustered together and here deposit alluvium throughout this region. Ning-chin Lake, Ta-lu Lake, etc., were included on maps published before 1926, but these lakes have since disappeared. San-ku-ting (between the lower reaches of Yung-ting Ho and the north section of Grand Canal) rose above the surrounding land level by 3-6 meters; the lake area had been fenced off with dikes to prevent flooding. The river beds were elevated, and tongue-shaped sand ridges were left behind on the plains after the deluge. Swamps south of Tientsin (Ch'i-li-hai, Hsiao-chan, etc.) have been artifically drained.

The coastline of the North China plain is shifting in the direction of P'o Hai, the change being most marked and rapid at the new Huang Ho Delta (fig. 11), with its apex at the neighborhood of Li-tsin about 80 kilometers from the sea.

Its broad slopes are submerged in water during the flow period (about 50 percent of Huang Ho silt is deposited here). The estuary blocked by the silt and subjected to tidal influences shifts from place to place, and many watermarks of deserted channels are clearly discernible in the rear of the delta. This area has been rapidly extended. Chronologically speaking, the average rate of expansion is estimated at 46 meters (12 AD - 1938 and 1495 - 1855 being taken as periods under observation). Recent surveys reveal that from 1949 to 1951 the fringe of the delta area within a limit of 46 kilometers had extended into the sea by 10 kilometers in three years. The Luan Ho Delta north of P'o Hai is diametrically opposite to the Huang-Ho Delta; its apex is located near Luan-hsien and its front is swept smooth by tidal action. It is a typical arcuate delta. The sand carrying capacity of Luan-ho is far below that of Huang Ho, proving that it had been in existence long before the formation of its present delta.

At the lower reaches of Liao Ho, the plains lie between the Jehol and east Manchuria mountain regions, linked to the Sung-nen plains in the northeast and marked by low relief at the dividing waterline. These two areas are popularly known as the Sung-liao and Northeastern plains.

The lower reaches of Liao Ho, except for a few granite domes, are mainly composed of broad alluvial plains [22]. Liao Ho meanders through a vast region, carrying a small volume of water but a great deal of detrital material. Many land-locked lakes are seen along its course. In the south the plain, originally a part of Liao-tung Bay, stretches continuously into P'o Hai as alluvial deposits increase in size and volume. South of New-chuang the swamps are at the mercy of tidal action even down at the present day [23].

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-- Managing Editor

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PART B—PERIODICALS

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- Kuliev, A.M. - Expulsion of one liquid by another from reservoir rock of nonhomogeneous permeability. p. 57.
- Mamedzade, M.S. - Flash floods in the mountains in the basin of the Tikanlychay River. p. 67.
- Motiakov, V.N. - Studying the movement of the oil-water boundary by means of electric models. p. 81.
- Agaeva, A.A., Alkehin, I.M. - Development of secondary oil recovery methods in Azerbaijan. p. 117.

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- Rafibeili, N.M. - Effect of hysteresis on well flow. p. 135.
- Bagbanly, E.A. - Determining the relation between pressure and saturation with the liquid phase in a dissolved-gas pool. p. 143.

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- Nodia, M. Z., Vekua, L. V. - Methodology for use in studying paleomagnetic changes. p. 277.
- Zhgenti, E.M. - Mediterranean elements in Karagan sediments in Georgia. p. 293.

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- Nazarenko, M. F. - Effect of the possible structure of an alkaline metal silicate melt on modifying changes in quartz. p. 74.
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- Sergienko, S.R., Lebedev, E.V. - Macromolecular n-paraffin hydrocarbons (C_{21} - C_{30}) from Romashkino (Devonian) crude oil. p. 16.
- Grashdan, P.E. - Chemical properties of water from mineral springs of the Gyaur anticline of the Kopet Dag. p. 20.
- Koliadnyi, S.N. - Analogs of the red series within the Balkhan Depression. p. 61.
- Bekmuradov, N. - Occurrence of bitumen in the red formation of Nebit-Dag. p. 64.
- Tamashaev, K. - Gypsum-salt tectonics in southeastern Turkmenistan. p. 67.
- Kravchinskii, Z.IA. - Some general features of the occurence of trace elements in oil field brines of Azerbaijan and Turkmenistan. p. 70.

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- Miklukho-Maklai, A. D. - Carboniferous stratigraphy of Central Asia. p. 20.
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- Eskin, F. I. - Effect of Atlantic waters on upper levels of Arctic seas. p. 153.
- Chochia, N. S. - Fourth All-Union Conference on the Study of Land Forms. p. 159.

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- Herun, H. F. - Paleogeographic and paleoecological conditions of the Kuyal'nik Basin in the region of Odessa. p. 311.
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- Shvebs, H.I. - Calculating surface erosion on the basis of data obtained by sprinkling. p. 337.

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Grigor'ev, N.F. - Some results of permafrost research in eastern Antarctica. p. 10.
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Markov, K.K. - Weathering in Antarctica. p. 9.
Kotliakov, V.M. - Marked differentiation of snow accumulation in the coastal regions of Antarctica. p. 13.
Ushakov, S.A., Lazarev, G.E. - Certain conclusions based on seismic and gravimetric observations along the profile Little America-Byrd Station. p. 17.

No. 10, 1959.

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Ushakov, S.A., Lazarev, G.E. - Thickness of the earth's crust along the meridional profile Davis Sea—Pionerskaya Station. p. 9.
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12. GEOGRAPHY & GEOLOGY

b. GEOGRAPHY

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Preface. p. 3.
Akimov, A.T. - Results of geophysical investigation of permafrost regions in the eastern part of the Bol'shezemel'skaya Tundra. p. 5.
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Polishchuk, N.K., Filosofov, G.N., Balobaev, V.T. - Conditions of the occurrence of frozen rocks in the Chul'man region according to electrometric data. p. 184.
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Lisitsyn, A.P. - Specific features of marine geological investigations in the Antarctic. p. 121.
Lisitsyn, A.P. - Marine geological investigations in the tropics. p. 153.
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Petrov, M.P. - "Central Asia" by V.M. Sinitsyn. p. 187.

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L'vov, Vladimir. - Geography and geology applied to the cosmos. p. 6.

c. GEOLOGY & PALEONTOLOGY

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AKADEMIIA NAUK SSSR. Geologicheskii institut. Trudy [ACADEMY OF SCIENCES OF THE U. S. S. R. Geological Institute. Transactions]. Moscow, no. 30, 1960.

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Arkhipov, S. A. - Quaternary stratigraphy, neotectonics, and paleogeography of the central Yenisey Valley. 170 p.
Title transliterated: Arkhipov, S. A. - Stratigrafiia chetvertichykh otlozhenii, voprosy neotektoniki i paleogeografii basseina srednego techeniia Eniseia. 170 p.

No. 36, 1960.

Title translated:
Klitin, K. A. - Tectonics of the central Tuva Depression. 123 p.
Title transliterated: Klitin, K. A. - Tektonika tsentral'noi chasti Tuvinskogo progiba. 123 p.

AKADEMIIA NAUK SSSR. Sovet po seismologii. Biulleten' [ACADEMY OF SCIENCES OF THE U. S. S. R. Council on Seismology. Bulletin]. Moscow, no. 7, 1960.

Title translated:
Gorshkov, G. P. - Seismotectonic problems and the divisions of the territory of the Chinese People's Republic into seismic regions. 53 p.
Title transliterated: Gorshkov, G. P. - Voprosy seismotektoniki i seismicheskoe raionirovanie territorii Kitaiskoi Narodnoi Respubliki. 53 p.

LENINGRAD. NAUCHNO-ISSLEDOVATEL'SKII INSTITUT GEOLOGII ARKTIKI. Sbornik statei po paleontologii i biostratigrafii [SCIENTIFIC RESEARCH INSTITUTE OF ARCTIC GEOLOGY. Collected Papers on Paleontology and Biostratigraphy]. No. 13, 1959.

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Savitskii, V. E. - Boundary between the Sinaean and Cambrian in the northeastern part of the Siberian Platform, Taymyr Peninsula, and Kharaulakhskiy Range. p. 5.
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Vasilevskaia, N. D. - Caytoniales and Cycadophyta from coal-bearing deposits of the Sangar region (Lena coal basin). p. 48.

No. 16, 1959.

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LENINGRAD. NAUCHNO-ISSLEDOVATEL'SKII INSTITUT GEOLOGII ARKTIKI. Trudy [SCIENTIFIC RESEARCH INSTITUTE OF ARCTIC GEOLOGY. Transactions]. Vol. 107, 1959. Sbornik statei po geologii Arktiki [Collection of articles on the geology of the Arctic].

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Egorov, L. S., Gol'dburt, T. L., Shikhorina, K. M. - Form and mechanism of the formation of the Gulya intrusions. p. 3.
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Obidin, N. I. - Classification of underground waters of the West Siberian Lowland and the Siberian Platform north of the Arctic Circle. p. 150.

MOSKOVSKOE OBSHCHESTVO ISPYTATELEI PRIRODY. Biulleten' [MOSCOW NATURALISTS' SOCIETY. Bulletin]. New Series, vol. 64. Otdel geologicheskii [Geological Section]. Moscow, vol. 34, no. 3, May-June 1959.

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12. GEOGRAPHY & GEOLOGY

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STUDIA GEOPHYSICA ET GEODAETICA. (Ceskoslovenska akademie ved. Geofysikalni ustav) Praha. [Journal on geophysics, meteorology, climatology, and geodesy issued by the Geophysical Institute, Czechoslovak Academy of Sciences. In English, French, German, and Russian with summaries in a language different from that of the article. Four no. a year]
Recurrent feature: News.

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Hradilek, L. Determination of the relative plumb-line deflections and the refraction coefficient in the nivellization of trigonometrically measured altitudes. In German. p. 334.

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Kaspar, M. Application of micromagnetometry in geologic surveying and its statistical directional evaluation. In Russian. p. 376.

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Vol. 5, no. 3, 1959.

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Vol. 8, no. 2, Feb. 1960.

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Balla, L. Activities of the International Bureau for Rock Mechanics affiliated with the German Academy of Sciences in Berlin. p. 69.

Pelnar, A. Study on mining methods in the Blue Shaft in the Zlate Hory Mountains; discussion of Pelnar's article and his conclusions. p. 70.

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Recurrent features: Readers' letters; Improvers' movement; New Soviet books; From our t...nical periodicals; Bibliography.

Vol. 38, no. 1, 1960.

Klement, K. Dolomite hydrates. p. 12.

Dempir, J. Complexometric determination of aluminum in mineral materials. p. 28.

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Recurrent feature: Bibliography

No. 5, Sept. 1959.

Kaljo, D.; Mark, E. Geologic development of Estonia in the Paleozoic era. II. p. 263.

Orviku, K. The "singing" sand. p. 302.

No. 6, Nov. 1959.

Loit, T. The teachings of Charles Darwin as the firm foundation of materialist biology. p. 325.

Vaga, A. Phylogeny of gymnosperms. p. 339.

Mardiste, H. An interesting group of boulders in Hiiumaa. p. 360.

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Vol. 2. [Petroleum in Nagylengyel; a final report] 1952. 58 p.

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Vol. 12, no. 3, Mar. 1960.

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Halasz, A. Preparation of quartz sand suitable for white glass manufacture. p. 98.

Budnikov, P. Dolomite as a raw material for building and refractory materials. p. 102.

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LATVIJAS PSR ZINATNU AKADEMIJA. Geologijas un derigo izraktenu instituts. Poleznye iskopaemye Latviiskoi SSR. [Otvetstvennyi redaktor N. A. Ansberg] Riga, Izd-vo Akademii nauk Latviiskoi SSR. [Mineral resources of the Latvian SSR. In Russian. maps (part fold.), bibl., tables]

Vol. 1. [Carbonate rocks] 1957. 147 p.

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LODZKIE TOWARZYSTWO NAUKOWE. Studia z geomofologii dynamicznej. Lodz, 1958. 268 p. (Its Wydzial III., no. 54. Acta geographica Universitatis Lodziensis, 8) [Studies on dynamic geomorphology. illus.]

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Tison, L. Henryk Arctowski and the "Belgica" Antarctic Expedition. In French. p. 296.

Coutrez, G. The "Belgica" Antarctic Expedition, 1897-1899. In French. p. 298.
Pietkiewicz, S. Henryk Arctowski's part in the Belgian Antarctic Expedition. p. 299.
Abbot, C. Dr. Henryk Arctowski's work with the Smithsonian Institution, Washington, 1939-1950. In English. p. 309.
Zienkiewicz, W. On Henryk Arctowski's works concerning the discontinuation of courses on meteorologic elements in time and space. p. 311.
Czekanska, M. Materials for Polish terminology in sea-ice categories. p. 321.
Halicki, B. Hammered-silver type structures on ice blocks in the English Bay, West Spitsbergen. p. 343.
Kozlowski, M. On the diurnal behavior of sudden commencements of storms at Chapa, Vietnam. In English. p. 349.
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Mikulski, Z. Floods in Poland. In French. p. 360.
Moniak, J. Isochrones of the Baltic Sea. p. 366.
Parczewski, W. Intensity of precipitation and frequency of electric discharges in thunderstorms. In English. p. 391.
Rojecki, A. Study of a discovered fragment of a three-hundred-year-old meteorologic data record made in Warsaw; a provisory communication. In French. p. 401.
Sawicki, L. The Polish glaciological expedition to Spitsbergen in 1938. p. 405.
Skorupa, J. Secular variations of the vertical component of terrestrial magnetism in the Sudetes and the Carpathian Mountains in the years 1952-1957. p. 419.
Slomka, J. Atmospheric extinction in Breslau in the years 1950-1955; a preliminary communication. p. 422.
Wierzbicki, Z. Air-saturation deficit in Poland. p. 430.
Wirkus, F. A graphical method of constructing 1000 mb prognostic contour charts. In English. p. 442.
Wiszniewski, W. Some remarks concerning meteorologic seasons of the year in Poland from the point of view of normal temperatures. In English. p. 467.

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KWARTALNIK GEOLOGICZNY. (Instytut Geologiczny) Warszawa. [Journal on the geology of Poland and related subjects issued by the Institute of Geology; with English and Russian summaries. Quarterly]
Vol. 2, no. 4, 1958.
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Maciejowska, J.; Serafin, J. Geochemical investigations in the northeastern part of Gory Kaczawskie with consideration of the history and methods applied in geochemical investigations up to the present time. p. 653.
Wieser, T. Petrotectonics of the intrusive mass of the Klodzko-Zloty Stok. p. 673.
Pawlowska, K. New data on lamprophyres from the Iwaniska region in Gory Swietokrzyskie. p. 688.
Ksiazkiewicz, M. Contacts of volcanic rocks in Kamionna near Bochnia. p. 706.
Tomczyk, H. Middle Ludlovian sediments found while boring at Zebrak near Siedlce; preliminary information. p. 711.
Senkowiczowa, H. New data on the Middle Triassic in the northeastern region of Poland. p. 722.
Dadlez, R. Geologic researches on the Pomeranian anticlinorium in 1957. p. 740.
Osika, R. The profile of the Upper Lias and Dogger in the vicinity of Zlotow near Bydgoszcz. p. 765.
Malinowska, L. Stratigraphy of the Lower Malm in the vicinity of Wodna near Chrzanow on the basis of its microfauna. p. 785.
Cieslinski, S. New data on the stratigraphy of the Albian, Cenomanian, and Lower Turonian in the region of Burzenin on the Warta River. p. 801.
Tokarski, A. Types of structures of the trans-Carpathian elevation. p. 807.
Stemulak, J. Deeper geologic structures of the region between the Olza and Biala rivers. p. 825.
Bieda, F.; Ksiazkiewicz, M. The age of the Babia Gora sandstones. p. 841.
Nowak, W. New location of fossil findings in the Godula beds. p. 857.
Fortunat, W. Specific gravity of clays. p. 860.

PRZEGLAD GEOGRAFICZNY. POLISH GEOGRAPHICAL REVIEW. (Polska Akademia Nauk. Instytut Geografii) Warszawa. [Issued by the Institute of Geography, Polish Academy of Sciences; with English and Russian summaries. Quarterly]
Recurrent features: Book reviews; Brief notes.
Suppl. to v. 31, 1959. In English. Tr. from the Polish.
Galon, R. New investigations of inland dunes in Poland. p. 93.
Kondracki, J. Studies on the natural landscape of the Masurian Lake district. p. 111.
Starkel, L. Development of the relief of the Polish Carpathians in the Holocene. p. 121.
Jahn, A. The raised shore lines and beaches in Hornsund and the problem of postglacial vertical movements on Spitsbergen. p. 143.
Information about geographical institutions in Poland; state for January 1, 1959. p. 179.

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PRZEGLAD GEOLOGICZNY. (Wydawnictwa Geologiczne) Warszawa. [Publication on economic geology issued by Geologic Publications. Monthly]
Recurrent features: Organizational and legal problems; Brief notes; New publications: reviews and foreign periodicals; Standards and instructions.
Vol. 7, no. 10, Oct. 1959.

JENKO, FRANC. Hidrogeologija in vodno gospodarstvo krasa. The hydrogeology and water economy of Karst. Ljubljana, Drzavna zalozba Slovenije, 1959. 237 p. [English summary. illus., maps (part fold.), bibl., graphs]

RAMOVS, ANTON, ed. Geoloski izleti po Sloveniji. [V Ljubljani] Mladinska knjiga, 1958. 215 p. (Mladi geolog, 2) [Geologic excursions through Slovenia. illus., maps]

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Vol. 10, no. 1, 1959.
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Ababi, V. Distribution of various forms of manganese in the mountainous soils of the Suceava region. II. Manganese in the soils evolved from crystalline schists. p. 113.

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GEOLOSKI VJESNIK. (Zavod za geoloska istrazivanja Hrvatske i Hrvatsko geolosko drustvo) Zagreb. [Papers issued by the Institute for Geologic Research of Croatia and the Croatian Geologic Society; with English, French, and German summaries]
Recurrent feature: Book review.

Vol. 12, 1958 (published 1959).
- Ogulinec, J. Annual report of the Institute for Geologic Research of Croatia for 1957. p. 9.
- Golub, Lj. A report on the work of the Croatian Geologic Society from November 1956 to December 1957. p. 17.
- Golub, Lj. A report on the work of the Croatian Geologic Society from December 12, 1957 to October 15, 1958. p. 19.
- Pavlovsky, M. Heterostegina and their finds in Croatia. p. 23.
- Kranjec, V. Contribution to the geology of the Sibenik-Vinisce region. p. 37.
- Crnolatac, I.; Milan, A. Contribution to the knowledge of promina deposits in Lika. p. 49.
- Polsak, A. Rudistae and some other fossils in the vicinity of Vrpolje and Perkovic in Dalmatia. p. 53.
- Jurkovic, I. Appearance of barite in Croatia. p. 77.
- Malez, M. Contribution to the knowledge of cave bears in Cicarija, Istria. p. 95.
- Jurkovic, I. Magnetite deposits in the Muhamedbegova Prisjeka region, near Kljuc in Bosnia. p. 115.
- Jurkovic, I.; Zalokar, B. Notes on the minerals in the Wuntho region, Burma. In English. p. 125.
- Herak, M. Contribution to the hydrogeology of Hvar Island. p. 135.
- Krulc, Z. Application of the geoelectric method to the geophysical testing in the construction industry. p. 149.
- Anic, D. Characteristics of flora and climate of the Tertiary in Yugoslavia. p. 191.
- Maric, L. Mineral facies in metamorphic rocks of Medvednica, the Zagreb Mountain. p. 205.
- Miletic, P.; Kranjec, V. Geologic relationships in the Jala River valley, the Tusla Basin. p. 219.
- Jurkovic, I.; Zalokar, B. The ore occurrences of the Shangalon area, southwest of Kawlin, Upper Burma. In English. p. 235.
- Babic, Z. Contribution to the geology of the Ivanscica Mountain between Lobor and Selenica. p. 269.
- Miladinovic, M. Notes on the finds of anhydrite in the layers of the Upper Cretaceus near Ulcinj. p. 273.
- Zalokar, B. Boris Tribusson (1924-1957); an obituary. p. 279.
- Malez, M. Dr. Ottokar Kadic; an obituary. p. 280.
- Kochansky-Devide, V. Contribution to the geologic bibliography of Croatia. I. 1956-1958. p. 282.

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NAFTA. (Institut za naftu) Zagreb. [Journal issued by the Naphtha Institute. Monthly]
Recurrent features: Bibliography; Book reviews; Petroleum dictionary.

Vol. 11, no. 1, Jan. 1960.
- Sikosek, B.; Uccellini, S. A characteristic profile of the Adriatic region. p. 7.
- Rizen, V. Slide rule for boring while prospecting. p. 12.
- Kocakov, D. Petroleum of the Sahara in the world petroleum industry. p. 14.